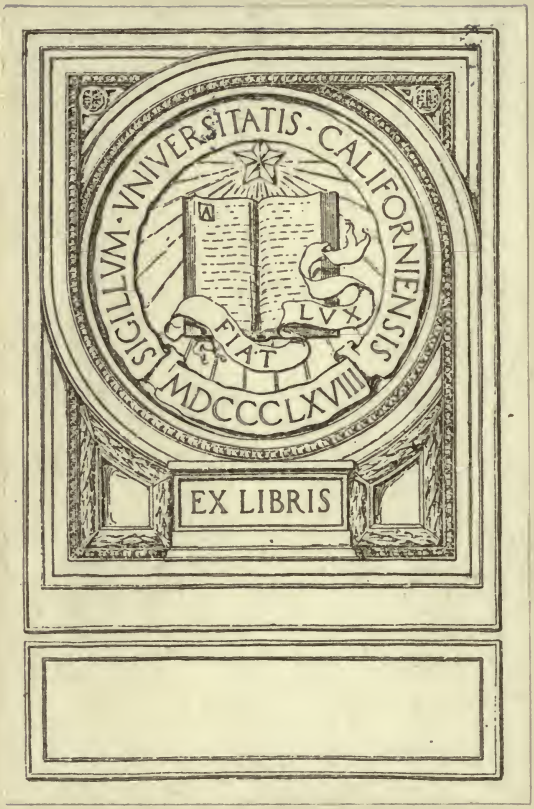
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WHALEBACK STEAMER

MERCHANT VESSELS

BY

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IN THE UNIVERSITY OF PENNSYLVANIA

D. APPLETON AND COMPANY
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1921

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EDITORS' PREFACE

THIS is the fourth volume of a series dealing with the business of ocean shipping and transportation. The first volume, *Ocean Steamship Traffic Management,* by Professor G. G. Huebner, bore the following Editors' Preface:

"This volume upon the management of ocean steamship traffic is the first of a series of manuals designed to assist young men in training for the shipping business. The necessity for such a series of manuals became evident when, as a result of the great war, the tonnage of vessels under the American Flag was, within a brief period, increased many fold. To carry on the war, and to meet the demands of ocean commerce after the war, the United States Government, through the Shipping Board and private shipyards, brought into existence a large mercantile marine. If these ships are to continue in profitable operation under the American Flag, the people of the United States must be trained to operate them. Steamship companies, ship-brokers and freight forwarders must all be able to secure men necessary to carry on the commercial and shipping activities that make use of the ships. A successful merchant marine requires ships, men to man the ships, and business organization to give employment to the vessels.

"In its Bulletin upon 'Vocational Education for Foreign Trade and Shipping' (since republished as 'Training for Foreign Trade,' Miscellaneous Series No. 97, Bureau of Foreign and Domestic Commerce, for sale by the Superintendent of Documents), the Federal Board for Vocational Education includes among other courses suggested for foreign trade training two shipping courses upon subjects with which exporters should be familiar, namely, 'Principles of Ocean Transportation' and 'Ports and Terminals.' Although such general courses are helpful to the person engaging in the exporting business, a training for the steamship business as a profession requires much greater detail in the knowledge of

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concrete facts of a routine nature. An analysis was made of the various divisions of the steamship office organization and it was suggested to the United States Shipping Board that as no literature existed of sufficient practicability and detail, several manuals covering the principal features of shore operations should be written.

"The response of the Shipping Board was hearty. The Shipping Board appointed Mr. Emory R. Johnson of its staff, then conducting an investigation of ocean rates and terminal charges, as editor. The Federal Board for Vocational Education designated Mr. R. S. MacElwee, then engaged in the preparation of studies in foreign commerce. Before the project was completed Mr. Johnson severed his connection with the Shipping Board, in 1919, and in January, 1919, Mr. MacElwee became Assistant Director of the Bureau of Foreign and Domestic Commerce, Department of Commerce. The interest of the editors in the project did not terminate, however, and their close coöperation has been voluntarily continued out of conviction that the works will be helpful.

"The books have been written with a view to their being read by individual students conducting their studies without guidance, also with the expectation that they will be used as class textbooks. Doubtless colleges, technical institutes, and high schools having courses in foreign trade, shipping business and ocean transportation will desire to use these volumes as class texts in a manner outlined in 'Training for the Steamship Business,' by R. S. MacElwee, Miscellaneous Series 98, Bureau of Foreign and Domestic Commerce, Superintendent of Documents, Washington, D. C. It is expected that evening classes and part-time schools organized under the patronage of the Federal Board for Vocational Education, Chambers of Commerce, and other interested organizations will find the manuals useful. Should these volumes accomplish the desired purpose of giving the American people a somewhat greater proficiency in the business of operating ships, they will have proven successful."

This volume upon *Merchant Vessels* contains a non-technical, amply illustrated description of the main types of vessels and their uses in different services. The discussion of the many problems connected with the measurement of vessels, their registra-

tion, and their tonnage is especially clear and valuable. The book should be of interest to all students of ocean transportation, to shippers, to vessel-owners, and to those engaged in the operation of vessels.

THE EDITORS

AUTHOR'S PREFACE

THIS is one of a "Shipping Series" designed as a basis for instruction in the various phases of the steamship business, a series inspired and outlined by the editors, Dr. Emory R. Johnson and Dr. R. S. MacElwee. As a part of such a series it assumes the form of a specialized text, supplementing and being supplemented by the other volumes of the series; but an effort has been made to describe a definite phase of the steamship business and in this particular field to produce a volume complete in itself. It deals with the vessels of various types and equipment employed in maritime commerce, their measurement and classification.

Part I describes the competition between sail and steam; the uses of the sailing vessel; wood, steel and concrete ships and their more essential parts; the various types of vessels employed and their uses; and the principal kinds of marine engines. In this Part the types of vessels and their purposes have been given exceptional space. The treatment is intended to be economic in character and no pretense is made of writing a technical treatise; on the contrary the sections dealing with construction features and marine engines have been made as clear and brief as possible and the advantages and disadvantages of the various features emphasized. The diagrams are intended to give accurate general impressions rather than mechanical details and photographs have been employed in some cases. Much of the information contained has hitherto existed only in such scattered form as to be inaccessible to the average student of transportation.

Part II deals with a phase of shipping activity upon which the available literature is noticeably scant. Aside from brief general remarks, government documents and foreign works, comparatively little information has been available on the purposes of vessel measurement, the units and methods employed, vessel measurement rules and the work of classification socie-

ties, in spite of the political, legal and economic significance of these subjects. American rules, practices and institutions have been emphasized, since foreign examples have often been presented elsewhere.

In preparing the list of references which appears at the end of nearly every chapter the endeavor has been to include those which are accessible and which contain a reasonable amount of additional material on the subject in a form suitable for the average reader, avoiding the usual complete but cumbersome "bibliography," which fortunately is elsewhere available. Unfortunately but inevitably this often excluded excellent and valuable books, sometimes those from which the author derived considerable assistance but whose technical character or inaccessibility made them unavailable for the purpose.

It is a pleasure to acknowledge the benefit derived from the advice and assistance of Dr. Emory R. Johnson and the information furnished by the Bureau of Navigation, the Collector of Customs at Philadelphia, officials of the Shipping Board, Mr. G. P. Taylor of the American Bureau of Shipping and vessel owners.

ROBERT RIEGEL

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PART I

CONSTRUCTION, TYPES AND USES OF MERCHANT VESSELS

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CHAPTER I

METHODS OF PROPULSION

In a study of the carriers of maritime commerce the distinction between the sailing vessel and the steamer is a primary concept. As to present-day functions of these craft, the circumstances which led to the decline of the sailing vessel, and the qualities which made steam preëminent as motive power, popular opinion includes many misconceptions. Steam vessels were not immediately an overwhelming success, did not, in fact, displace the sailing vessel as fast as the automobile has displaced the horse, and, to carry the analogy further, are still inferior to the sailing vessel under some circumstances, as the motor vehicle is to the horse for a limited kind of service. It is impossible here to revise these conceptions by a history of the development of vessels but this chapter will serve to distinguish the sailing vessel of to-day from its predecessors of various types, to explain the disappearance of this form of propulsion and to indicate its few remaining uses. Thus some of the modern characteristics of water carriers will be emphasized by contrast with the materials and methods of the past.

Classification of Sailing Vessels

The larger sailing vessels may be grouped in classes according to "rig" or arrangement of sails, the number of masts, and the form or shape of hull. The principal methods of rigging are the "square rig" and the "fore-and-aft rig," though in small sailing vessels peculiar variations have been introduced by custom and convenience. The number of masts has tended to increase with the increased size of vessels, made possible by improvements in materials, methods of construction and mechanical handling, until a maximum of seven has been reached. The subject of form may be dismissed here with the statement that it developed from the bluff-bowed vessel with a "beam" or breadth one-fourth of its length, as illustrated in the English vessels in the West Indian

trade of the early nineteenth century, to the narrower schooner and "clipper" ship, with concave water lines at the bow, beam only one-fifth or one-sixth the length and relatively great breadth well aft. Other developments in form of hull are discussed later.

A "square-rigged" vessel is one with the yards supporting square sails extending across the masts, approximately equal lengths of yard and equal sail areas extending on each side. The following illustration of a full-rigged ship shows the arrangement, some subsidiary sails being added — jibs, staysails and spanker.

In the "fore-and-aft" rig the yards and booms do not cross

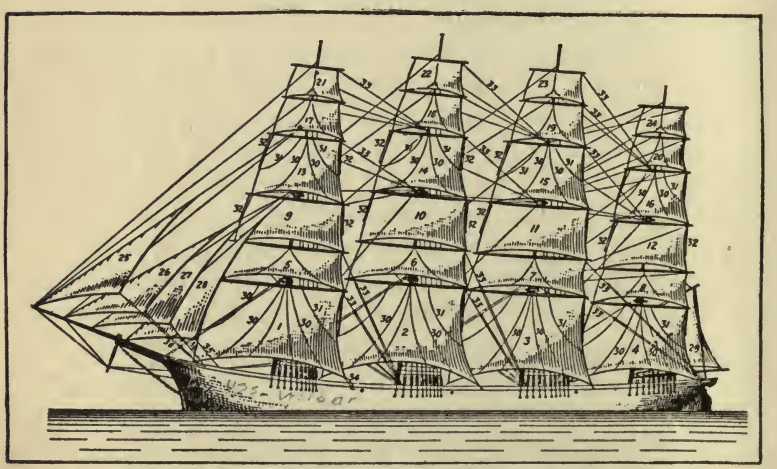

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FIG. 1.— FULL RIGGED SHIP

the mast but extend on one side only, the sails therefore not being square but tending to approach a triangular form. The yards and booms move with one end resting on the mast as a pivot. Figure 2, a modern schooner, will serve as an illustration.

Various combinations of these two styles of rigging on vessels with one or more masts produced the types: (1) ship, with three or more masts, all square-rigged; (2) bark, with three or more masts, all masts except the after-mast square-rigged; (3) barkentine, with three or more masts, the two after-masts fore-and-aft rigged; (4) brig, with two masts both square-rigged; (5) brigan-

tine, a brig without a square mainsail; (6) the sloop, with one mast fore-and-aft rigged; (7) the schooner, with two or more masts fore-and-aft rigged. The last-named is the sailing vessel type of primary importance to-day.

The schooner has steadily increased in size, owing largely to the introduction of machinery for hoisting and lowering sails and

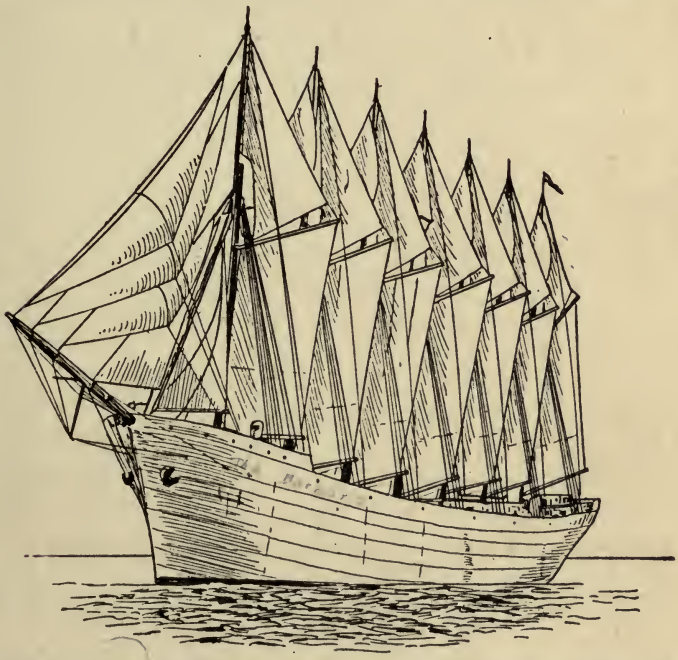

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FIG. 2.— SCHOONER — *Thomas W. Lawson*

anchors, until in 1902 the *Thomas W. Lawson,* a seven-masted steel schooner of 5218 tons gross register was launched. This vessel had a spread of 43,000 square yards of canvas and was manned by a crew of 18. In 1890 an 1800-ton vessel with five masts was considered large and until the introduction of labor-saving machinery as low as 900 tons marked approximately the limit of size. The schooner has usually a greater proportionate beam than the steamer, a high freeboard or distance from water line to deck, great sheer (curvature of deck) forward, and an unobstructed deck from forecastle to bridge, which is located well

aft (see illustration, page (5). Both the square and fore-and-aft rig have advantages in different winds and weathers, but the fore-and-aft is more manageable, thus reducing the crew and operating expenses. It is estimated that the seven-masted schooner described above, if square-rigged, would require a crew of 40 men to handle her instead of a crew of 18.

Decline in Importance of the Sailing Vessel

But all of the various types of sailing vessels except the schooner have been driven out by steamers, and the usefulness of

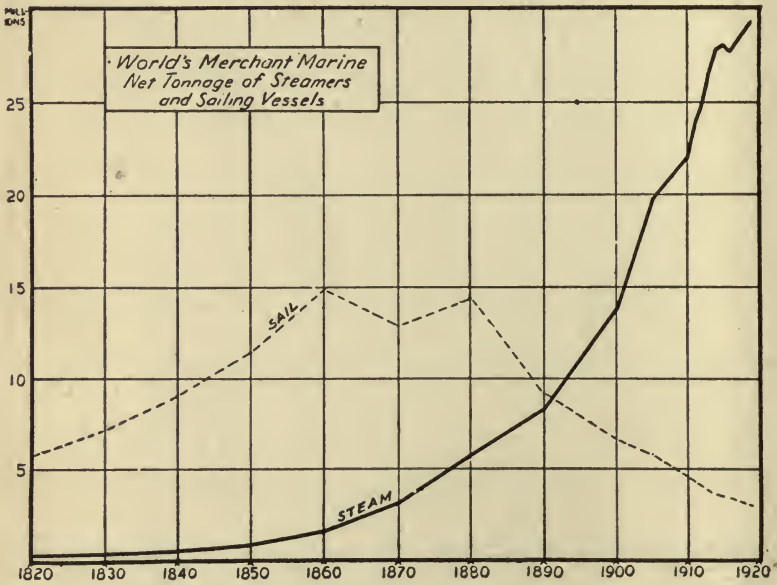

Fig. 3

even this form is exceedingly limited. This elimination of the sailing vessel resulted, not from the unexceptionable superiority of the steamer, but because the advantages of the latter outweighed the good features of the former. Thus, in some trades, such as to the Far East, the competition between the two was keen for a comparatively long time and only great improvements in steam propulsion finally gave it supremacy.

By reference to the above diagram it will be seen that the sailing vessel, as regards the world's merchant marine, could not maintain its position after 1880. In 1860 sailing vessels con-

tributed 89 per cent of the total tonnage; in 1870, 81 per cent; in 1880, 71 per cent; and by 1890, only 53 per cent. At the present time sailing vessels form less than 10 per cent of the total tonnage of the world, and even this figure exaggerates their importance because of the many insignificant vessels which are included to form this aggregate.

In spite of the impulse which the development of early steam

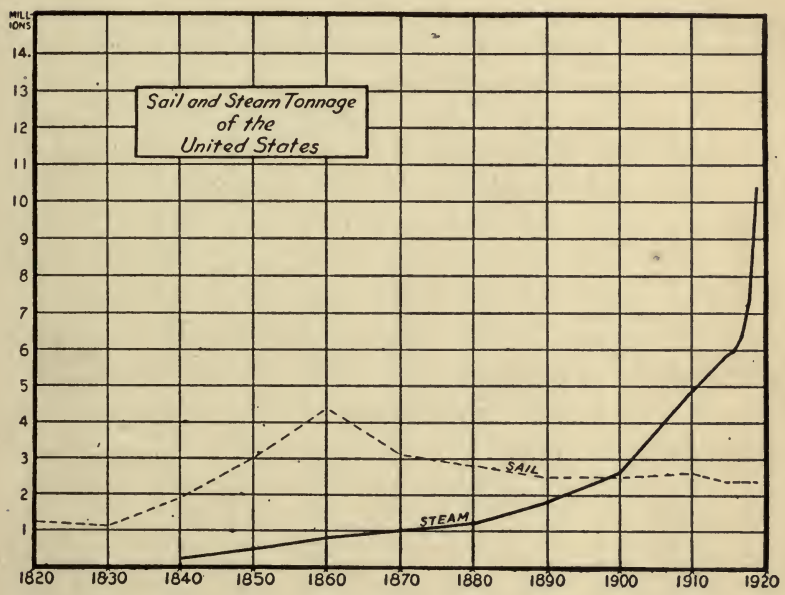

FIG. 4

navigation received in the United States we continued longer than foreigners to attempt to use the sailing vessel as a competitor of steam, as illustrated by the above diagram. Thus, in world commerce in 1900, 32 per cent of the tonnage was sail, while over 49 per cent of American tonnage was still propelled in this manner. To put it in another way, the world fleet was composed almost equally of steam and sail tonnage shortly after 1880, while American steam tonnage did not equal sail until nearly 1899. The facts are equally well stated by saying that the sail tonnage of the United States has declined more slowly than that of the world, but we have not kept pace in the acquisition of steam vessels.

Advantages of Steam Over Sail

It will throw some light upon the nature of present-day commerce to indicate the reasons for the supplanting of sail by steam.

1. **The Superior Regularity of Steam-Propelled Vessels.**— In the early days of steam vessels they were subject to great handicaps because of the inferior nature of the engines utilized for the work and the consequent heavy consumption of fuel. It is a mistake to suppose that the steamer everywhere outstripped the sailing vessel; the latter held its own on some routes for years. But one manifest advantage possessed by the steamer, in spite of its deficiencies, was that of regularity. A sailing vessel might make the voyage from London to Australia in 60 days with a good passage, but, on the other hand, it was equally likely that the trip would consume half again as much time. The date of the sailing vessel's arrival was purely a matter of conjecture, and commercial projects based upon it were therefore merely tentative in nature. As an illustration, in the cotton business 45 years ago the contracts were entirely for delivering the product "on the spot" and "on arrival." A contract for delivery by some definite future date, such as now constitutes the majority of transactions, was an impossibility, because of transportation conditions. A little later it was practicable to make a future contract specifying delivery within two named months and at present a merchant can name the day of delivery. For the same reason, contracting for vessel space in advance, an almost universal practice now, was beset with many difficulties. As a matter of fact, in those early days, a steam vessel with a speed of 8 or 9 knots was superior to a sailing vessel on the average, although the latter might attain double that speed. Too much importance can hardly be assigned to this factor of regularity, for steamship men testified in an investigation of rates and practices in 1913 that in modern commerce the primary factors of importance were regularity and dependability of service and rates. A glance at the map on page 10 will show the difficulties experienced by the sailing vessel. The larger and more important sailing routes of the world are shown here and some of the important constant winds, it being impossible on a map of this size to indicate all the routes or even more than a few of the winds. The map is sufficient to show, however, that the sailing vessel was limited in its routes by the

direction of the winds; that the seasons of the year might affect the length of the voyage, as for instance in the Indian Ocean, where the space on the map is insufficient to show the well-known seasonal winds; that deviations from direct paths were necessary to take advantage of favorable winds, as for instance the routes between the 40th and 60th parallel south to obtain the benefit of the westerly winds, or on a voyage from Panama in a northerly, southerly, or westerly direction working south and west as far as the Galapagos Islands before obtaining favorable winds and currents, or bound from New York to the West Coast of South America via Magellan the deviation eastward nearly to the Canary Islands to obtain the assistance of the trade winds and pass Cape St. Roque, Brazil; that deviations were necessary to avoid unfavorable winds and currents as in circling the southeast trade winds in the South Atlantic; that calms might be experienced anywhere and were particularly imminent in certain localities; and so on, innumerable illustrations being available in books containing sailing directions. The map on page 10 shows some of these sailing routes.

2. The Higher Average Speed of the Steamship.— In many trades speed is a highly important transportation quality, as, for instance, in the transportation of perishable commodities and the trade in highly competitive products where service plays a large part in the price. The steamship gradually demonstrated that on the whole it would not only be more punctual, but would give steadily superior service as far as the element of time was involved. Subsequent developments of engines, boilers, propellers, etc., merely accentuated this superiority. Thus the voyage from Panama to San Francisco is performed by a 9-knot steam freighter in 15 days, while the average for a sailing vessel is 37 days. From New York to San Francisco via Straits of Magellan took a sailing vessel 140 days while a steamer of 9-knots could make the distance in approximately 60 days. Interest on the money involved in a shipment may be an important consideration. Thus silk shipments from Japan may involve interest charges on a sum as large as a $1,000,000 and in many trades the shipments will involve interest on sums ranging from $25,000 to $200,000. Obviously sailing vessels under such conditions fall in the class of expensive luxuries rather than economical carriers.

N.E. Trade Winds
S.E. Trade Winds
Calms
Generally Westerly Winds
N.E. Trade Winds
S.E. Trade Winds
Calms
Generally Westerly Winds

3. Greater Efficiency of the Steamship.— While at first the steamship was a voracious consumer of fuel and on early voyages the vessel not uncommonly was compelled to utilize the spars and woodwork for this purpose, it subsequently became considerably more economical. Furthermore, the fuel difficulty was very greatly reduced by the establishment of numerous coaling stations in all parts of the world. The steamer attained superiority in the long distance trades, however, only after considerable effort. It is popularly assumed for statistical purposes that, considering the superior efficiency of the steamer, sail tonnage should be divided by four to put it on a basis with steam.

4. The Development of Canals an Additional Handicap to Sailing Vessels.—The Suez Canal, for example, which was opened for traffic in 1869, reduced the distance between New York and Bombay by 3400 miles, and the distance between New York and Hong Kong by nearly 3000 miles, yet the absence of regular winds in the Red Sea prevented the sailing vessel from taking advantage of this route. The same deficiency in Panama Bay restricts the use of this waterway by sailing vessels.

The sailing vessel had some points in its favor, however, and these have enabled it still to remain in some trades where it has special uses. These favorable features are (1) motive power without cost; (2) a large net cargo, no space being occupied by boilers, engines, coal bunkers, and shaft which in a steamer consume from one-fourth to one-third the hull capacity; (3) a smaller minimum crew with a few highly skilled men. A sailing vessel of 2400 net tons might require a crew of 34 of whom 22 are seamen while a steamer of similar size shipped a crew of 38, of whom 11 were seamen and 17 engineers, firemen, and coal passers. On a large and slow steam vessel the crew may average as low as one man per 100 tons net register but the average for a similar sailing vessel may be even lower. One writer has described the struggle between sail and steam as "a competition between low costs and low efficiency, and high cost and high efficiency, and high efficiency is winning."

Present Uses of Sailing Vessels

1. The sailing vessel still remains somewhat of a factor in connection with certain trades, for example, the coasting trade, which

is not readily organized. Here a definite amount of tonnage is not regularly available and the return is not large enough to warrant the investment of the additional capital required for a steamship or the expenditure of coal necessary to call where cargo is uncertain. Thus, in the coastwise trade the steamers are largely engaged as combination passenger and freight liners and the tramp freighting is relinquished to sailing vessels and towed barges. On the Pacific Coast large wooden schooners are considerably used but often equipped with auxiliary steam or gas engines. The Great Lakes trade is not adapted to the use of sailing vessels. The vice president and general manager of the Clyde and Mallory Steamship Companies testified in an investigation that not a single port on the Atlantic Coast would, with the business originating at the port and without feeding from the interior by railroad lines, maintain even temporarily the services now furnished by established lines of steamers. The majority of sailing vessels are employed on the Atlantic and Gulf Coasts and are operated as tramps, being chartered for a voyage or a longer period, the illustration of the *Thomas W. Lawson* on page 5, showing the highest development of the schooner. This vessel was used for the carriage of coal between Norfolk and New England ports, having a capacity of about 8000 tons of this product. Eventually, because of her deep draft, she was removed from this trade and transformed into an oil carrier, because unable to load her full cargo at either Philadelphia or Baltimore. This vessel

SAIL TONNAGE OF UNITED STATES, 1906 AND 1916

Tonnage Class	1906		1916	
	Number	Tonnage	Number	Tonnage
5– 49	4,255	72,734	1,337	26,619
50– 99	685	47,731	335	22,989
100– 199	353	51,219	180	26,005
200– 299	242	60,491	118	29,484
300– 399	205	71,241	90	31,146
400– 499	224	100,796	91	40,927
500– 999	718	517,208	502	371,688
1000–2499	388	581,046	303	465,362
2500–4999	57	181,465	43	141,827
5000 & up	4	20,345	3	15,127
Total	7,131	1,704,276	3,002	1,171,174
Average		239		390

was a seven-masted, double-bottom steel schooner of 5218 tons gross register and 4914 tons net. The lower masts and bowsprit were constructed of steel tubes.

The above table, taken from the Census Report of 1916, brings out several interesting facts regarding the sail tonnage of the United States. While the number of vessels declined by over 57 per cent, the total gross tonnage declined by only 31 per cent; while great decreases in tonnage are apparent in vessels of up to 500 tons gross, the decreases are less noticeable in vessels of over 500 tons. In other words, such sailing vessels as tend to remain in operation are those of greater size.

2. The use of sailing vessels may be temporarily increased by changes in conditions of construction and operation. Thus a period of insufficiency of steam tonnage may make the sailing vessel temporarily a profitable enterprise, so profitable at the time as to more than counterbalance the possible future difference in usefulness. Thus the period of the World War saw steam tonnage at a premium and absolutely necessary for navigating the war zone, while sailing vessels were temporarily utilized for performing work ordinarily done by the steamer. The United States Government, for example, put steamers on the route to France and utilized French sailing vessels to supply the deficiency in other trades so created. The period 1899–1900 saw a revival of the sailing vessel because of the scarcity of ships, the high ocean freight rates, and the high price of steel.

3. The sailing vessel may be a factor in any trade where the cost of investment is a highly important consideration. In some lines of business the return would not be sufficient to cover the loss of interest on an expensive vessel, and the wooden sailing vessel may be built for perhaps 20 per cent less than one of another type.

4. A similar use is sometimes found for the schooner in ocean traffic with countries where the trade is very irregular and poorly developed. The sailing vessel may provide a cheap method of attempting to develop a regular trade.

5. In the carriage of bulk cargoes the sailing vessel still remains an agency of some importance. Coal, lumber, grain, nitrate of soda, and sugar have always been considered particularly suitable cargoes for sailing vessels. One of the few regular sailing lines from the United States is the Benner Line to Porto Rico, of whose

DISTRIBUTION OF VESSEL TONNAGE IN UNITED STATES AS OF JUNE 30, 1916

	Sailing Vessels		Steam Vessels		Motor Vessels		Canal Boats and Barges		Total	
	No.	Tons	No.	Tons	No.	Tons	No.	Tons	No.	Tons
Atlantic and Gulf.....	4,686	861,226	3,534	2,658,093	5,197	88,755	2,937	823,076	16,354	4,431,151
Porto Rico.....	80	9,161	10	2,569	9	143	....	.....	99	11,873
Pacific Coast.....	416	254,759	1,002	681,108	2,296	56,512	1,360	122,422	5,074	1,114,801
Hawaii	7	3,494	22	11,895	22	868	....	.....	51	16,257
Northern Lakes.....	191	182,225	1,560	2,434,603	775	9,915	525	134,072	3,051	2,760,815
Western Rivers.....	2	72	696	106,827	938	18,774	179	9,079	1,815	134,752
Total	5,382	1,310,937	6,824	5,895,095	9,237	174,968	5,001	1,088,649	26,444	8,469,649

exports sugar is approximately three-fifths in value. A large portion of the nitrate trade from Chile to Europe and the Atlantic ports of the United States was formerly handled by sailing vessels but this business has been extensively invaded by the steamer. Other illustrations of the use of the sailing vessel are found in the jute trade of India, the grain trade of California and British Columbia, and the transport of nickel ore from New Caledonia. Sailing vessels, even after the demonstrated superiority of steam, continued to carry much of the coal and lumber on the Atlantic coast; in the coal trade the schooner barge has come into prominence. There are still numerous important lumber fleets on the Pacific Coast and this is the principal occupation of the sailing vessel in this region; some experienced maritime men still believe that a wooden five-masted sailing schooner, with single deck and a carrying capacity of approximately 1,500,000 feet of lumber is the most economical vessel in this business, because of safety without ballast, cheap motive power, and lower construction cost. Bulk products have continued to be carried by sailing vessels because they are usually shipped as full vessel cargoes, do not require rapid transportation, and prompt delivery is a negligible factor. It was formerly believed that in some of the long-distance trades, as for instance to Australia and to the Orient, the sailing vessel would always remain a competitor of considerable importance, but experience to date has not verified this opinion. Wherever the business is regular in character the steamer has found extensive employment.

6. The system of bounties in vogue in certain foreign countries to some extent renders possible the continued competition of sailing vessels.

The following table shows the distribution of steam and sail tonnage of the seagoing merchant vessel (500 gross tons and over) of the United States, as reported by the United States Shipping Board on February 28, 1919.

	Number	Gross Tonnage
Steamers	1,338	4,390,479
Tankers	174	950,175
Sailing vessels	390	442,357
Schooner barges	354	384,693
Total	2,256	6,167,704

Of the above 390 sailing vessels 157 were acquired between July, 1914, and February, 1919. One hundred were of new construction, 38 obtained by foreign purchase, 12 converted from other types, and 7 seized from Germany. The losses to sailing vessels during this period, however, were even greater than the acquisitions, totaling 251 vessels of 270,908 gross tons, mostly by marine risks.

To summarize, then, the fore-and-aft rigged vessel in the form of the schooner alone of the various sailing vessels survived the competition of steam, and a considerable increase in its size and the development of mechanical aids were necessary for economical operation. The expensive but efficient steamer reduced the proportion of sail from 90 to 10 per cent of the world's tonnage; though this took place more slowly in the United States than elsewhere. The former had superior regularity, higher average speed, greater efficiency, and was helped and not hindered by canals. The latter had some advantageous features but these enabled it to remain only under particular circumstances, namely, (1) in the coasting trade which is not readily organized, (2) temporary changes in constructing and operating conditions, (3) where cost of investment is primarily important, (4) in irregular and poorly developed ocean traffic, and (5) in the carriage of bulk cargoes in the coastwise business and on a few ocean routes.

REFERENCES

1. O'Donnell, E. E.: *The Merchant Marine Manual.* The Yachtsman's Guide. Boston, 1918. Pp. 58–73. (On the various types of sailing vessels.)
2. Johnson, E. R., and Huebner, G. G.: *Principles of Ocean Transportation.* D. Appleton & Co., New York, 1918. Chap. I. (On the various types of sailing vessels.) Chap. V. (On ocean routes.)
3. Kirkaldy, A. W.: *British Shipping.* Paul, Trench Trübner & Co., London and New York, 1914. Chaps. V, VI, VII, and VIII. (On the gradual ascendancy of the steamer.)
4. Smith, J. R.: *Organization of Ocean Commerce.* Publications of University of Pennsylvania, Series in Political Economy and Public Law, Philadelphia, 1905. Chap. VII. (On the gradual ascendancy of the steamer.) Chap. VII. (On the sailing routes of the world.)

5. JOHNSON, E. R.: "Panama Canal Traffic and Tolls," report to U. S. Secretary of War, 1912. Washington, D. C., 1912. Appendix I. (On industrial and commercial value of the Isthmian Canal.) Chap. IX. (On the handicap to sailing vessels of canal routes.)
6. Reports of the U. S. Commissioner of Navigation. Annually. Washington, D. C. (Giving statistics of the American merchant marine.)
7. *Pacific Marine Review*, February, 1919, pp. 108–111. (Description and diagrams of sailing-vessel rigs.)

CHAPTER II

MATERIALS OF CONSTRUCTION

The object of this chapter is to classify vessels with reference to the materials from which they are commonly constructed. These include principally wood, iron, steel, and concrete, and by a combination of steel and wood the "composite" ship is obtained. In order to compare intelligently the vessels produced from these materials it is necessary to examine briefly the principal parts of the earliest type of vessel — the wooden ship. This will also serve later as a basis and a background for the description of the modern cargo carrier — the steel vessel. Since it is impossible here to scrutinize the engineering and architectural details of the wooden ship the description and illustrations will be reduced to their simplest elements, omitting many features which are unessential for present purposes. Numbered references after the terms used are to the diagram on page 20.

Principal Parts of a Wooden Ship

The *keel* (1) is the foundation or backbone of the vessel. The various other members of the vessel are all, in a sense, supported by the keel. So important is this part that it is protected against the damages of grounding by a *shoe* (2) lightly bolted to its bottom, which may be torn off without material injury to the keel itself. At the bow end of the keel is placed the *stem* (3), which is fastened to the keel by a hook-scarf, a method of dovetailing which prevents pulling apart longitudinally. At the stern end of the keel is fastened the *sternpost* (4) by tenon and mortise.

Next is placed in position the larger portion of the "ribs" of the ship, designated the "square-frame," and including all the individual *frames* (5) or ribs which are fastened to the keel. Some others at the bow and stern must be otherwise attached and supported. These U-shaped frames are raised from the ground by a derrick and placed in position across the keel. Each frame

is constructed from several frame-timbers joined together and the joints are arranged so that no straight joining line runs the length of the keel; to make the joints all at the exact center of the keel would be unnecessarily to impart an element of weakness. Above the keel, parallel with it, and resting on the frames is laid the *keelson* (6), which is fastened by bolts through itself, the frames, and the keel. It gives additional strength to the union of keel and frames.

As the vessel becomes sharper toward the stem and stern it is impossible to attach all the ribs to the keel and these frames called *forward-cants* and *aftercants* (7) rest upon a mass of timber called the forward and after *dead-wood* (8), which is bolted to the stem, keel, and sternpost. The cants gradually incline toward the extremities of the vessel from a position at right angles to the deck to parallel with it, and give the curve to the vessel at the bow and stern.

The skeleton of the vessel is now in existence and is ready to be covered. Beginning at the keel the *outside planking* (9) is put on longitudinally, and inside the frames the *ceiling* (10) occupies a similar position. Individual planks of common reference are given names, such as the garboard strakes (the first two planks to be worked on the outside of the frame), and the sheer strakes (the top full course of planks at the deck level). Air is admitted between planking and ceiling by air strakes, which are merely spaces left in the ceiling. Before the ceiling can be worked up to the upper deck the intervening decks have to be provided for.

Heavy pieces of timber called *beams* (11) are laid transversely across the ship between and attached to the frames. These support and prevent the collapse of the sides of the ship and furnish a basis for laying a *deck* (12). They are also supported by *stanchions* (20). Running fore and aft from beam to beam are shorter pieces of timber called *carlings* (13). These support the deck at places where openings must be cut. Running transversely between the beams are smaller timbers, *ledges* (14), which are let into the carlings. The terminations of the beams are reënforced by *knees* (15), natural growths of timber forming nearly a right angle, which are used as braces. Openings called *hatches* (16) are let into the decks for the purpose of loading and unloading cargo, etc., and framed by fore-and-aft timbers called

hatch coamings (17). The hatches are shown uncovered in the illustrations. At the stern may be seen the *rudder* (18), and above the top deck the *bulwarks* (19).

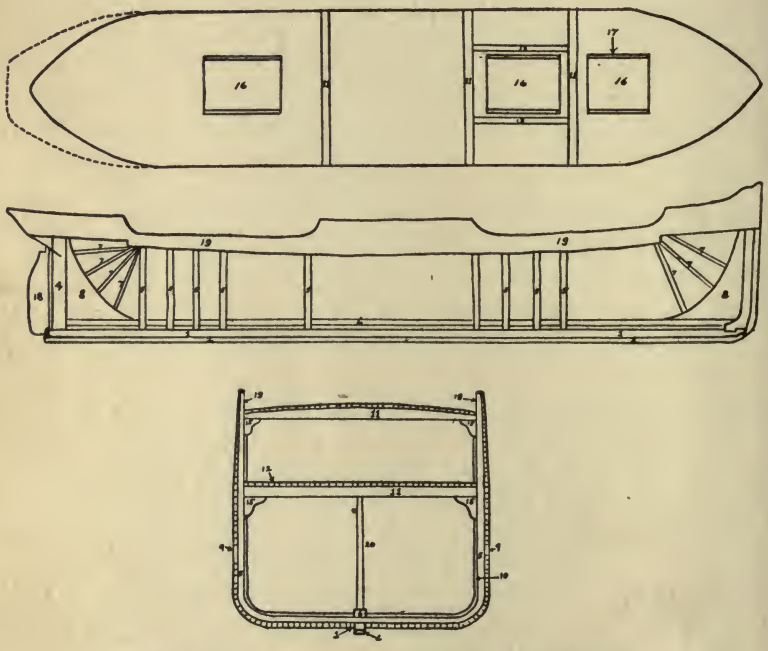

FIG. 6.— PRINCIPAL PARTS OF A WOODEN VESSEL

DISADVANTAGES OF WOOD AS A SHIPBUILDING MATERIAL

Wood was the natural material for the construction of vessels because of its abundance, the ease with which it could be worked, and its buoyancy. In the United States it continued to be used as a material even after other nations had begun the change to iron. The early steamers were wooden vessels, and it was even for a time contended that iron vessels would not float. But with the development of steam power and the gradual increase in the size of vessels, due to the discovery that large units could be more economically operated than small, the defects of wood as a material became more and more apparent. These were as follows:

1. Except in the United States, wood became increasingly diffi-

cult to obtain. Soft wood would not yield first-class results, and oak was becoming expensive.

2. The iron vessel, despite the high specific gravity of the material, was lighter than a wooden vessel. While the individual plates would sink, if placed in water, the ship had not the same specific gravity as its material, a large part of its cubic contents being air. A vessel will float as long as its enclosed water-tight volume, expressed in cubic feet, is greater than its total weight in tons multiplied by 35, since 35 cubic feet of sea water weighs 1 ton. To put it in another way, 35 cubic feet of sea water will support 1 ton of 35 cubic feet capacity. Therefore, the ratio of the cubic capacity of the vessel to the unit 35 cubic feet determines the maximum weight of a floating vessel. In the early wooden vessels the weight of the hull and fittings aggregated from 35 to 45 per cent of the total displacement, whereas in an iron vessel of the same size these two contributed only from 25 to 35 per cent of the total displacement. By the utilization of iron there was a saving of approximately one-fourth in the weight of the hull, and this in spite of the fact that these more or less experimental vessels contained far more metal than was afterward found necessary.

3. To attain equal strength the wooden ship required keel, beams and frame of far greater thickness, one inch of iron being much stronger than one inch of wood. This meant that the iron vessel had more carrying space and carrying power in proportion to its outside dimensions and, consequently, a greater earning power. As shown by the figures above, of every 100 tons displacement in the wooden ship about 40 tons were hull and fittings and about 60 tons cargo. In the iron vessel similarly loaded of every 100 tons displacement about 30 tons were hull and fittings and 70 tons cargo.

4. The iron vessel was apparently capable of indefinite expansion in size, and in fact in our time metal vessels have been limited in size more by canals and terminal facilities than by inherent engineering difficulties. The wooden vessel, on the other hand, owing to the nature of the material, was practically limited to a length of 300 feet [1] and the most successful were not much more than 200 feet long.

[1] Compare with the *Minnesota*, 1905, 622 feet; the *Bismarck*, 1914, 912 feet.

5. The use of iron increased the structural strength even irrespective of size. About 1834 the *Garry Owen,* an early iron vessel, was driven ashore with many wooden vessels without serious injury, while the others were almost total losses; and in 1843 the *Great Britain,* an iron vessel of then great size, stranded on the Irish coast and remained on the beach all winter with but little injury. These cases were at the time convincing object

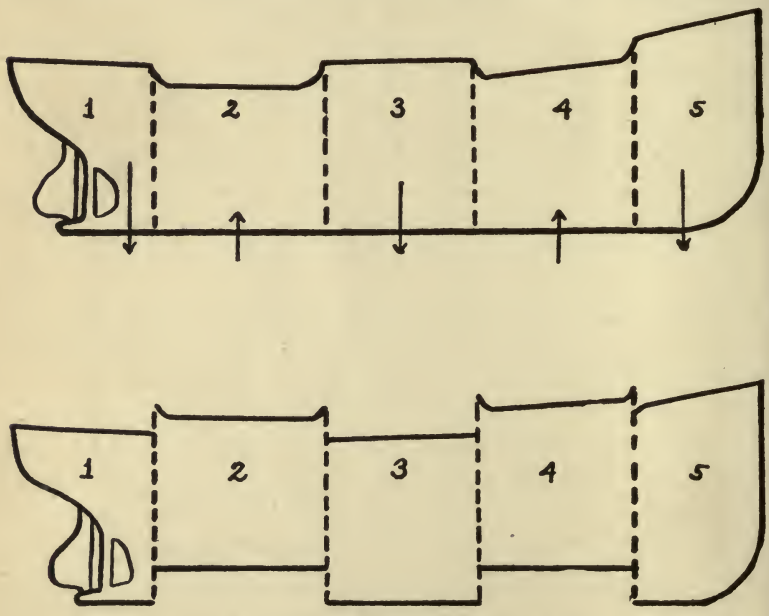

FIG. 7.— VESSEL STRESSES IN STILL WATER

lessons of the value of iron as a shipbuilding material. Even under ordinary circumstances a vessel is subjected to stresses of many kinds, tending to produce distortions called " strains." The above illustration shows a cargo vessel floating light and divided into imaginary parts and, since the parts themselves have weight and buoyancy, the existent stresses even under these conditions.

There are, therefore, vertical forces tending to bend and break the keel, to crack stanchions of wood, loosen the frames and planking. By the loading of cargo these stresses are increased.

At sea other stresses appear. The two following illustrations show those developed by the actions of the waves.

In one case, the vessel is fully supported amidships but without support at the extremities with consequent tendency to "hog." In the other, the extremities rest upon the waves but the integrity of the middle portion depends largely upon the strength of material and workmanship with consequent tendency to "sag."

By rolling in the waves, furthermore, there is a tendency for a vessel to alter its transverse form, as in the following illustra-

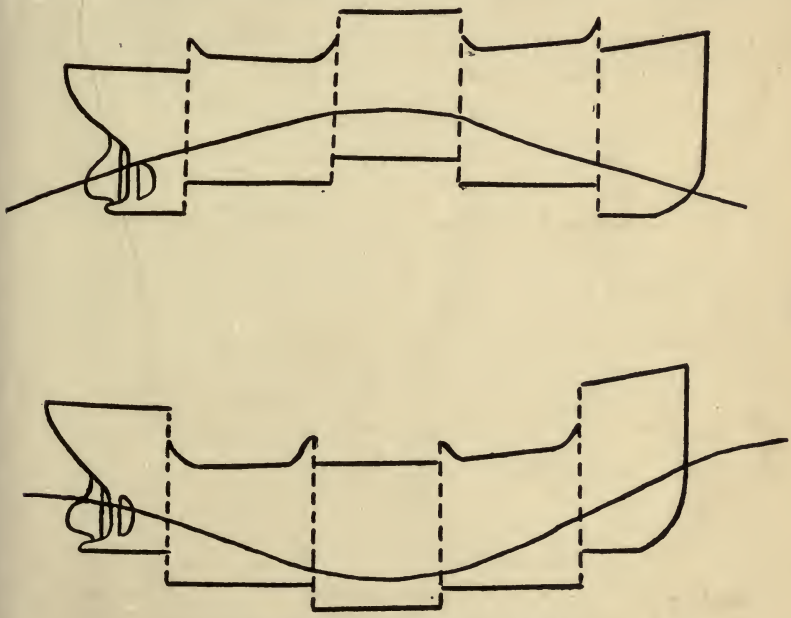

FIG. 8.— VESSEL STRESSES IN WAVES

tion. This tears the stanchions away from the keel, distorts the position of the frame, separates the beams from the frame, or separates the several portions of the frame, destroys the alignment of stem, stern, and keel, and opens gaps in the planking or covering.

It would be possible to enumerate other stresses to which vessels are subject, such as the head resistance at high speed, the pounding on the bottom at the fore part of the vessel, and the stresses of loading, but the foregoing is sufficient to partially illustrate the difficulty of attaining satisfactory results in wooden vessels of great size.

6. The iron vessel was better suited to resist the constantly in-

creasing weight and vibration accompanying the development in size of the marine engine. This vibration subsequently became an important engineering problem even in connection with metal vessels.

7. The metal vessel was superior in point of view of fire-resisting qualities. In 1909 the *Celtic*, a White Star liner between New York and Liverpool, was on fire while at sea, and by the use of tarpaulins and injections of steam the fire was controlled until the *Mersey* was reached. A wooden vessel would probably have ended her existence in the Atlantic.

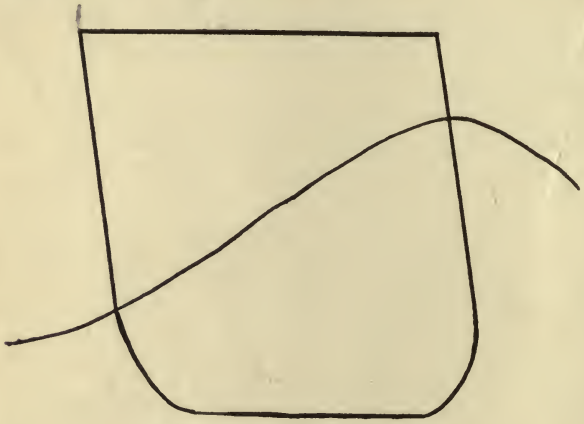

FIG. 9.—TRANSVERSE STRESS

8. As a corollary to the above might be mentioned the more favorable marine insurance rates which may be obtained both by the owner of the metal vessel and the shipper of cargo therein, by reason of its superior seaworthiness and resistance to fire.

As against these manifest advantages, the wooden vessel could only offer the original ease with which its material could be obtained and worked and a lower cost of construction, factors which were entirely insufficient to offset the weighty arguments in favor of the stronger material. As a result, the metal vessel became the common type of merchant carrier. No effort will be made here to trace the history of the early metal vessels, which are fully described in many excellent historical works, and we will proceed to an examination of the characteristics which gave steel preeminence as a material.[2]

[2] See references at the close of this chapter.

Advantages of Steel

Iron was subsequently superseded by steel, which was first used by the French in 1873. The advantages of the latter material are:

1. An ultimate tensile strength (measure of stretching force) from 25 to 30 per cent greater than that of the best iron ship-plates.

2. Ductile (capable of being elongated) and malleable.

3. Homogeneous in substance and uniform in quality.

4. The strength is the same in all directions, whereas iron plates frequently showed 15 per cent greater strength tested lengthwise than breadthwise.

5. The ratio of the elastic limit (point where elasticity ceases) to the ultimate breaking strain is greater than in the case of iron; therefore, the working loads borne by the steel exceed those of the iron.

6. In the earlier vessels classed at Lloyd's there was a saving of from 13 to 15 per cent in weight by the use of steel, with increased cargo and fuel space thereby.

7. Although the cost was originally greater, the increased cost was compensated for by the augmented capacity. As far back as 1881 one writer worked out the following comparison of cost and capacity for a spar-decked steamer of 4000 gross tons carrying passengers and cargo in the Eastern trade[3]:

Weight of iron in iron steamer.....	2123 tons,	costing £14,501
Weight of steel and iron in steel steamer	1847 tons,	costing £18,075
Difference — increased dead-weight capacity of steel steamer.....	275 tons,	costing £ 3,574

The figures showed that the extra 275 tons dead-weight capacity would compensate for the extra cost in a little more than two years. Later steel vessels could be built for even less than iron would cost.

As a result of the advantages described metal vessels tended to displace wood ships. In 1860, 30 per cent of the British tonnage consisted of iron vessels, and by 1919, 99 per cent was com-

[3] W. Denny, *Transactions of the Iron and Steel Institute*, Great Britain, quoted in Holmes, *Ancient and Modern Ships*, p. 44.

posed of iron and steel. In the United States iron was little used before 1870, and before the World War 35 per cent of the tonnage was wooden vessels, although this is partly due to the coasting trade. The table at the close of this chapter is illustrative of present conditions in the American merchant marine.

The Composite Vessel

The composite vessel is really a metal vessel in every particular except the shell, which is of wood. While the prejudice against iron existed in 1851, it was nevertheless admitted that there would be a considerable gain in lightness and space by substituting iron frames and beams for the heavy wooden ones and in that year the *Tubal Cain*, 787 tons, was built at Liverpool in this style. Between 1860 and 1870, with the Suez Canal unopened and steamers unprofitable on the long voyage in the China tea trade, the clean bottom obtained with a copper sheathing over wooden planking was so important to a quick run home that a number of vessels were so constructed. They were iron-framed, planked with teakwood from 5 to 6 inches thick and fastened with Muntz-metal bolts. Teakwood was used because its natural oil is a preservative and it is the only wood which can be brought into contact with iron without injury to the iron or itself. A copper sheathing completed the vessel and gave perfect immunity from a foul bottom. But with the opening of the canal, steamers took over the tea trade, and although the composite vessels built gave good service, the advantages gained were an insufficient offset to their great costliness. The system became practically obsolete as regards merchant vessels, and is used only for yachts.

Iron and steel vessels are sometimes protected below the water line by having the iron or steel plating of the bottom sheathed with wood and the wood covered with copper sheets secured by copper nails. The copper must be carefully insulated from the steel hull to avoid galvanic action induced by sea water. Zinc has also been used on wooden vessels, but, although it gives protection from worms, it has no antifouling qualities. At one time pure copper was used but yellow metal has been substituted, for with powerful resisting qualities it is cheaper and lasts longer.

Concrete Vessels

Concrete was used for some years as a material for the construction of small crafts, barges, etc., but the shipbuilding difficulties of the World War suggested the possibility of applying this material to larger vessels. The demand for steel could not be equaled by the production of the steel mills, there was insufficient seasoned lumber for wooden vessels, and shipbuilding labor was utterly inadequate to accomplish the gigantic program mapped out. After investigation by the Bureau of Standards and the Shipping Board, a department of Concrete Ship Construction was created in the Shipping Board in December, 1917, and work begun on the development of standard designs for concrete cargo carriers. Contracts were placed with various yards and the program at the close of 1918 called for the production of 38 tankers and cargo vessels of 7500 tons dead weight, 3 cargo ships of 3500 tons dead weight and 1 cargo ship of 3000 tons dead weight. Barges are also being constructed for harbor and inland service.

In the ferro-concrete vessel, the framework is of steel, and similar in character to the steel vessel, but the covering is composed of a concrete composition of the highest possible elasticity and least possible weight. The process is either to cast the concrete in adjustable molds or to add steel rods and wire lath to the steel framework for strength and cohesion and plaster on the concrete mixture. The latter method is probably superior. In Norway small vessels are built by placing the concrete over an inverted wooden hull and launching the vessel bottom up.

The obstacles to the development of the concrete vessel were:

1. The great weight and volume of material necessary to attain the required strength. This was partially met by the production of a concrete mixture by government engineers, which would not only float but was one-fifth lighter than wood. It possessed nearly twice the strength of ordinary concrete mixtures. The following table prepared in England shows the excess weight of concrete as compared with steel, and indicates that this excess relatively declines with the size of the vessel.

2. Liability to crack under stress, the seriousness of which is disputed, some claiming for certain concrete mixtures almost the elasticity of steel. Numerous concrete vessels have been con-

Cargo capacity dead weight	Weight of steel hull	Weight of hull of reinforced concrete	Excess weight of concrete hull	Excess displacement of concrete hull
Long tons	Long tons	Long tons	Per cent	Per cent
500	250	475	90	30
1,000	550	950	75	26
2,000	1,050	1,650	57	20
3,000	1,500	2,200	46½	15½
5,000	2,200	2,800	27½	8½

structed in Norway. The illustration is cited of a concern which has built a successful seagoing concrete vessel of 200 dead-weight tons, a lightship of the same material for the Norwegian Government, and a 4000 ton ore-carrying ship.

3. Concrete is porous and subject to deterioration by salt water. To offset this, Shipping Board engineers have devised a protective coating.

4. As a cargo carrier the concrete ship is about 8 per cent more efficient than a wooden ship and about 5 per cent less efficient than a steel vessel.

The counterbalancing advantages are:

1. Speed of production, it being estimated that after the experimental stage is passed the concrete vessel will consume only one-half to one-third the time of steel construction.

2. Cheapness. One writer cites expert estimates of $60,000 worth of reënforced concrete for a hull of a 5000-ton cargo ship, as compared with $300,000 for a steel freighter of the same size. The report of the United States Shipping Board estimates the cost of a concrete vessel as $70 per dead-weight ton for the hull and $150 per ton, complete. A joint committee of the American Concrete Institute and the Portland Cement Association reported in 1918 a design for a concrete vessel of 2000 tons capacity on which the cost per dead-weight ton was estimated at $63. For steel construction of similar capacity the estimates ranged from $90 to $120, and for wood construction from $70 to $100.

3. Nonshipbuilding labor may be employed in its production, a factor of particular importance in time of labor scarcity. Construction companies claim that the labor employed is largely unskilled, that house carpenters may be used and ship carpenters

almost eliminated, and that the steel is fabricated and placed by a comparatively small group of men skilled in reënforcing steel, assisted by a large proportion of common laborers easily trained for the purpose.

4. Readily molded to form.

5. Easily repaired.

6. Vibration reduced, as evidenced by the experience with the *Faith,* a 5000-ton vessel launched at San Francisco.

It is evident that in a period such as we have just experienced the concrete vessel appears of considerable promise. Where production at any cost is the prime essential many shortcomings in service and durability may be overlooked, but the future of the concrete vessel is still doubtful. The latest work on shipbuilding states: "At the present concrete ships must still be considered as in an experimental stage, and until they have been built in sufficient numbers and operated satisfactorily for continuous and extended periods of time to demonstrate their practicability, the advisability of laying down large numbers of such vessels is open to some question." [4]

Present Uses of Wooden Vessels

The wooden vessel, though usually inferior to the steel carrier, may at certain times assume more than ordinary importance. Thus we have seen that wooden sailing vessels experienced a temporary popularity during the period of high steel prices in 1899 and 1900. During the World War tonnage of any kind was eagerly desired and since steel was unobtainable in sufficient quantities wooden ships became the next best thing.

The following table shows the number of vessels built and officially numbered in the United States since July, 1916, including vessels built for foreign owners.

But this was an unusual state of affairs. Freight rates were high, tonnage was insufficient, and vessels long considered to be obsolete and unseaworthy were resurrected from their resting places and made to do duty in a time of necessity. The wooden ship under ordinary conditions will never be a serious competitor as a cargo carrier. In the coasting trade where sailing vessels are used, in barges, in tugs where carrying capacity is not a factor of

[4] A. W. Carmichael, *Practical Ship Production,* New York, 1919.

	Year ending June 30, 1917		Year ending June 30, 1918	
	Number	Gross tons	Number	Gross tons
Seagoing				
Steel	114	468,502	252	1,031,976
Wood	80	131,449	158	215,716
Total	194	599,951	410	1,247,692
Non-seagoing	1,352	212,708	1,990	183,101
Total	1,546	812,659	2,400	1,430,793

importance and under circumstances where low investment is a dominant factor, however, wood will continue to be an important construction material. Even in the wooden vessel, of course, iron and steel have come to be extensively used for reënforcement.

The following diagram shows the classification of the world's

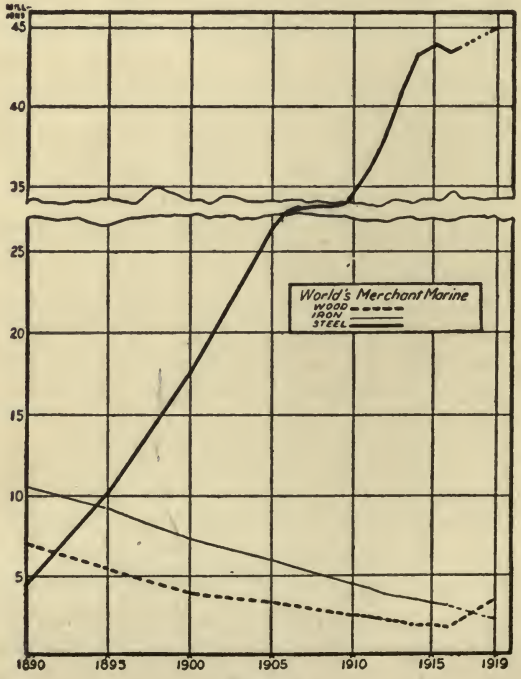

FIG. 10

merchant marine according to material of construction from 1890 to 1919:

CONSTRUCTION MATERIAL
WORLD'S MERCHANT MARINE *

	Wood	Iron	Steel
1890	7,053,885	10,517,513	4,435,208
1895	5,534,677	9,211,561	10,223,101
1900	4,009,622	7,398,102	17,508,704
1905	3,394,850	6,044,824	26,445,998
1910	2,544,858	4,548,599	34,728,700
1911	2,409,331	4,233,858	36,116,427
1912	2,270,558	3,981,056	38,263,659
1913	2,113,276	3,721,285	41,005,887
1914	1,983,458	3,529,097	43,465,210
1915	1,920,264	3,353,146	43,912,311
1916	1,856,176	3,154,091	43,596,761
1919	3,513,579	2,294,410	45,111,284

* Comm. Nav. Report, 1917, p. 66.

REFERENCES

1. O'DONNELL, E. E.: *The Merchant Marine Manual.* Boston, 1918. Pp. 74–85. (On the method of construction, principal parts, and nomenclature of a wooden ship.)
2. WALTON, THOMAS: *Know Your Own Ship.* Griffin & Co., Ltd., London, 1917. Chaps. III and IV. (On buoyancy of metal vessels and vessel stresses and strains.)
3. SPRINGER, J. F.: "Concrete Boats a Transportation Asset." *American Industries,* July, 1918, pp. 15–17. (Arguments in favor of the concrete vessel.)
4. KELLY, R. W., and ALLEN, F. J.: *The Shipbuilding Industry.* Houghton Mifflin Co., Boston, 1918. Pp. 74–79. (On the recent construction of concrete vessels by the Shipping Board.)
5. PORTLAND CEMENT ASSOCIATION: *Concrete Ships.* Chicago, 1917. (Arguments in favor of the concrete vessel.)
6. HOLMES: *Ancient and Modern Ships.* Wyman & Sons, London, 1906. (Development of iron and steel vessels.)
7. CHATTERTON, E. K.: *Steamships and Their Story.* Cassell & Co. London, 1910.

CHAPTER III

STRUCTURAL FEATURES OF STEEL VESSELS

To describe the structure of a building one would naturally describe the shape, position and methods of connecting the more important structural members. This would give a good conception of buildings in general, but however excellent the impression conveyed, it would not create a picture of any particular building. So in shipbuilding no general description will convey a picture of a particular vessel, for by variations in methods of construction and the introduction of individual features a vessel may acquire a distinctive personality. But the principal parts of every vessel are designed to serve in general the same purposes, regardless of its type or the material from which constructed. This chapter will serve to indicate these purposes, to form a basis for the discussion of vessel types partly dependent on structural features, and to make the reader acquainted with the nomenclature of the modern steel merchant vessel. In this a recollection of the preceding description of the structure of the wooden vessel will be useful.

The *hull* of a vessel consists of two parts, the *shell,* skin or enveloping plating, which in the wooden ship was planking made water-tight by calking, and the *frame,* which in a general sense includes all the principal members of the ship except the shell. The framing may be *transverse, longitudinal,* or a *combination* of both, which latter is frequently used. All frames, in fact, have longitudinal and transverse members, but it is possible to give greater emphasis to either group and the emphasis given tends to fix the name. Thus the Isherwood system of construction is designated as longitudinal framing, not because transverse members are lacking, but because there is continuity of the main framing which runs fore-and-aft and the auxiliary transverse framing is spaced wider than in the so-called transverse system.

We shall discuss first the transverse members, with which we have become familiar through the consideration of the wooden

ship. Transverse framing was emphasized in the wooden vessel and when iron replaced wood it was natural to continue the methods of the past and merely substitute the new material. The fundamental portion of the structure, as we have seen, is the keel, which is a longitudinal member running fore-and-aft, but is so basic that it must be considered here. In the wooden ship

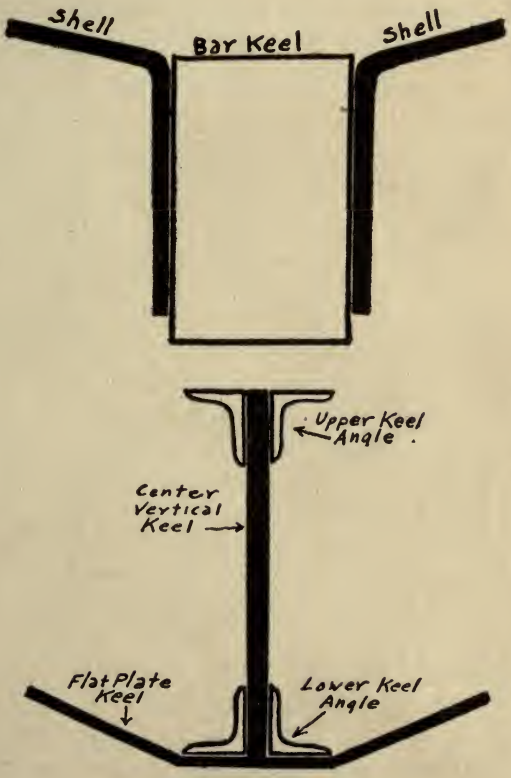

FIG. 11.— KEELS

the keel was a strong and heavy timber with a rectangular cross-section, and this was naturally replaced at first by a bar of heavy wrought iron of similar cross section, which is now called a *bar keel* (see Figure 11). The lower outside shell plating which is of steel, is bent so as to fit tightly to the sides of the keel and fastened with rivets extending through the keel. Although it has the advantage of strength and stiffness, this type increases the draft of the vessel without any corresponding addition to the

carrying capacity and, therefore, the tendency has been to replace it with the *flat plate keel* (see Figure 11). This is a long course of plating dished on each side, connected to the lower plates of the shell plating by a lap joint. On the flat plate keel rests a *center vertical keel* or *center keelson* (see Figure 11), for it partakes of the nature of both, being fastened to the flat keel by angle bars.

The transverse frames in the steel ship consist of steel bars instead of timbers. In very small vessels the cross section of these

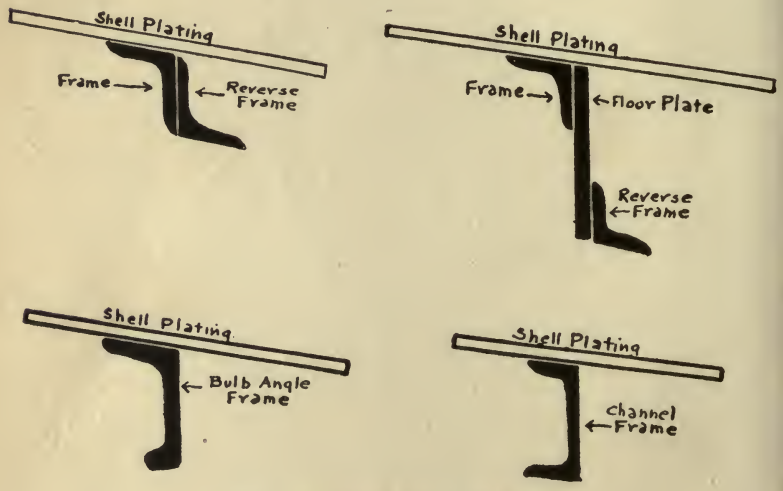

FIG. 12.— TRANSVERSE FRAMES

bars is the shape of a right angle (see Figures 12 and 13), but in larger vessels this is reënforced by a reverse frame of the same shape laid against it (see Figure 12), or other shapes such as the *channel, Z-bar* or *bulb angle* (see Figure 12) are substituted. The *frames* (see Figures 13 and 14) are attached to the flat and vertical keel at intervals of from 20 to 30 inches. The frames and *reverse frames* (see Figure 14) are joined together as they run down from the deck until the side of the vessel curves into the bottom, where the frame continues on to the flat plate keel to serve as a foundation for the outer shell while the reverse frame separates from it by a gradually widening space and finally is attached to the upper portion of the center vertical keel. Thus there is a space between the outer and inner bottom, the frame serving as a foundation

for the former and the reverse frame for the latter. The frames give shape to the vessel, support the shellplating against the

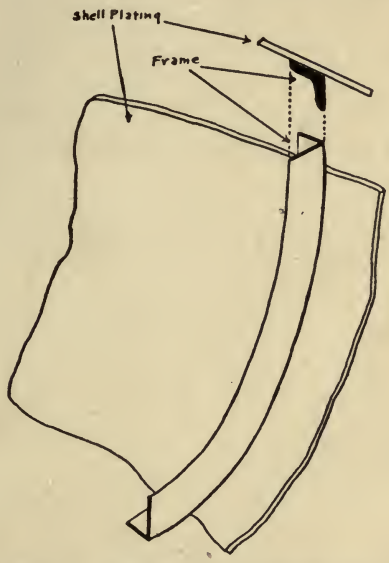

FIG. 13.— FRAME AND SHELL PLATING

water pressure, serve as a basis for a double bottom, transmit vertical forces carried by the decks to the bottom of the ship, and encounter the stresses of " rolling."

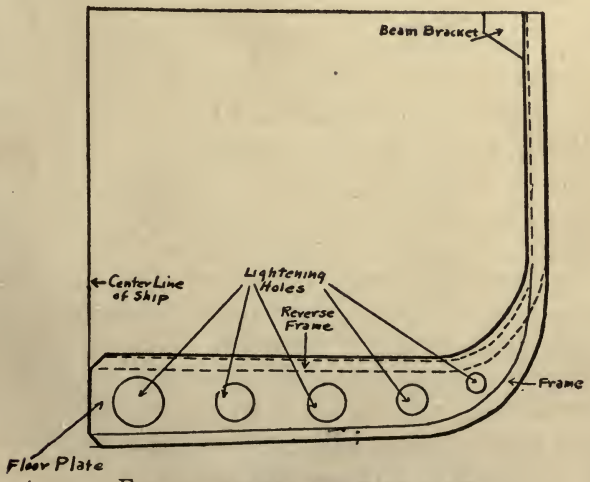

FIG. 14.— FRAMES AND FLOOR PLATE

For purposes of strengthening the bottom of the ship, plates called *floor plates* are fitted between the frame and the reverse frame and thus the construction of the bottom comes to resemble the construction of a floor in a house (see Figures 14 and 17). The floor plates are attached to the center vertical keel by short pieces of angle bar, and in order to reduce weight, lightening holes are cut in the plates (see Figure 14). The floor plate is carried around the turn of the bilge as it strengthens what would otherwise be a weak spot, especially in a square-bilged

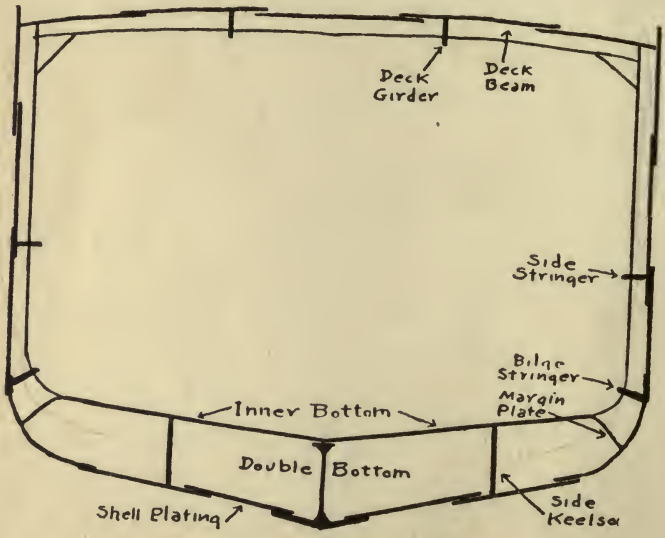

FIG. 15.— KEELSON AND STRINGERS

ship, because "working" is more likely here when the vessel is exposed to the action of the waves.

The *beams* (see Figures 15 and 16) are steel bars, channel-shaped or bulb angles, connecting the uppermost extremities of the frames (in a single-decked ship) and connecting the frames at other lower points in a vessel with more than one deck. If the frames be considered as the walls, then the beams perform the same functions as the beams of a house. They prevent the frames from spreading due to the weight of cargo, or from closing like an umbrella due to pressure of water, and they serve as a foundation for the decks. It is necessary that the connections of parts of a vessel should be very efficient, and the beams are connected

to the frames by *beam knees* or brackets (see Figure 14). Where a hatch opening is necessary for loading and unloading, the beams do not extend across the vessel from frame to frame, but are only "half-beams" supported by *carlings* (see Figure 16).

The beams in a large vessel are comparatively long pieces of steel and the longer a bar the less rigidity it possesses. There are inserted under the center of the beams, therefore, and resting on the center keelson, *pillars* or *stanchions.* This is equivalent to shortening the beam one-half and consequently adding to its strength. In addition, by tying together several beams, it tends

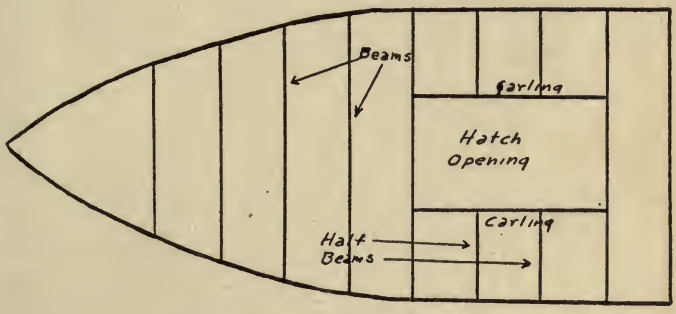

FIG. 16.— BEAMS AND CARLINGS

to cause the entire combination of parts to act as one piece; otherwise any great force exerted on the side of the ship would cause the beam to bend upward at the center. Since it is advisable in many cases to keep the hold or lower part of the vessel as clear as possible for cargo, the elimination of hold pillars and hold beams is aimed at and secured by equivalent reënforcements of another nature, described later.

Bulkheads are partitions. They may be either longitudinal or transverse, but the former are little used on merchant ships due to the necessity of keeping the hold space sufficiently broad. Transverse bulkheads naturally produce transverse strength and give support to decks. In addition, however, they subdivide the ship lengthwise into a number of holds or compartments and thereby limit the flooding produced by a puncture of the shell plating. They form, in other words, a number of water-tight compartments so that leakage is localized and safety considerably increased (Figure 18).

A common feature of modern vessels is the *double bottom* (see

Figure 17). This is formed by plating over the tops of the floor plates curving down to the outer shell plating at the sides. Thus there is formed an outer and an inner bottom. This feature might be continued up the sides so as to give the vessel a complete double shell under water, as in the large passenger liners, but ordinary cargo vessels have it only to the bilge.

Turning attention now to the longitudinal members, they all may be classified according to location into two groups, those between bilge and keel, or *keelsons*, and those on the sides above the bilge,

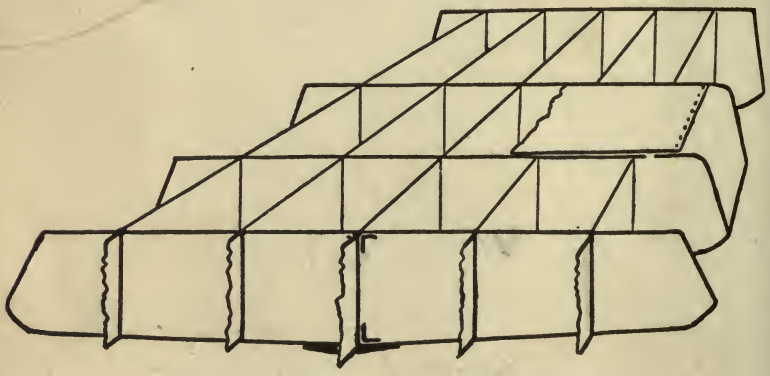

FIG. 17.— FLOOR PLATES AND DOUBLE BOTTOM

or *stringers* (see Figure 15). The most important keelson is the *center keelson* (see Figure 11) which is above the keel and runs the length of the vessel. On either side of the center keelson and about midway between it and the bilge are the *side keelsons* (see Figure 15), which prevent the floor plates from tilting. These are termed intercostal girders because they are composed of plates fitted intercostally between the floors in a continuous line fore-and-aft and attached to them by angles. The next keelson is on the bilge and is termed the *bilge keelson* (not shown in Figure 15). The number of keelsons will vary with the size and type of ship. Working up the side of vessel, just above the bilge is the *bilge stringer* (see Figure 15), and then the *side stringer* (see Figure 15).

It has been stated that the construction of the vessel may be varied to meet the purposes for which intended. The classification societies provide rules for the construction of vessels in order to meet their approval, but alternatives are provided for

attaining the required structural strength. The alternatives principally are (1) a vessel constructed with hold beams such as has been described, (2) web frames provided in lieu of hold beams, that is, the floor plates continued up the side of the vessel, (3) deep framing, composed of two angles fitted together so as to form an extra heavy frame. Hold pillars may also be dispensed with in some cases where an unobstructed hold is required. This is practically a continuation of the floor plates or partial bulkheads.

Another system of framing of present-day importance is the

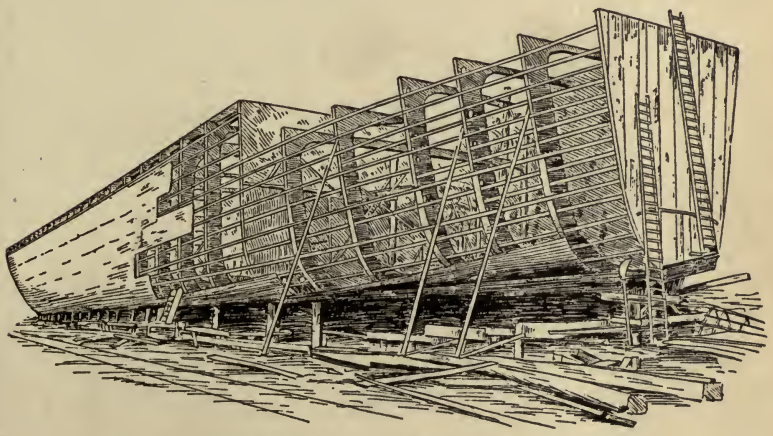

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FIG. 18.— LONGITUDINAL SYSTEM

Isherwood system, in which emphasis is placed on the longitudinal members of the hull. The main frames run fore-and-aft, and the transverse frames are at greater intervals than usual. The outstanding feature is the continuity of the longitudinal members, which are multiplied in number. The method is exceedingly well-adapted to oil tankers, for which it is in almost universal use. Twelve hundred vessels have been, or are being built by this system, aggregating 9,500,000 tons dead-weight capacity, including 400 bulk oil carriers of 3,600,000 tons dead-weight capacity.

The transverse frames and beams, in the Isherwood system, are at widely spaced intervals of about 12 feet and form complete transverse belts around the vessel. They are directly riveted

to the shell plating and deck of the vessel, and are often of greater strength than the transverse frames of the ordinary form of construction. The outer edges of the transverse frames are slotted, however, to permit the fitting of continuous longitudinal keelsons or stringers at the sides, bottom, and decks. The method is not new, in a sense, the idea having been employed in the

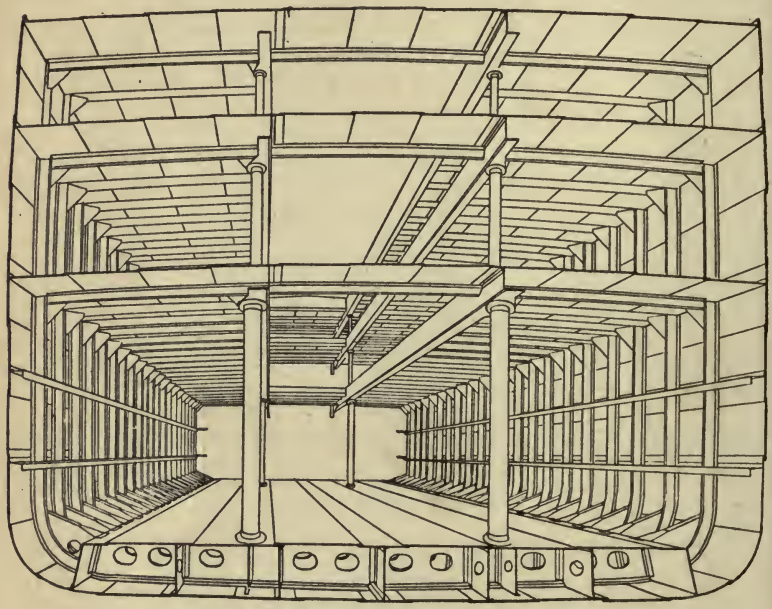

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FIG. 19.— TRANSVERSE SYSTEM

construction of the *Great Eastern,* a 680-foot transatlantic vessel constructed in 1858, but at that time it was cheaper and easier to build on the old system. The following illustrations will convey the idea of the Isherwood system better than any description. Figure 18 is a photograph of a vessel under process of construction, while Figures 19 and 20 contrast interior views of the transverse and longitudinal systems.

The advantages claimed for this type of construction may be summarized as follows:

1. Increased dead weight, by dispensing with a number of transverse connections, such as beam knees, bilge brackets, tank knees, packing, etc., and reduction of the longitudinal frames in

accordance with the water pressure. The increased dead weight, for example, in a two-deck cargo vessel 500 feet by 58 feet 4 inches by 35 feet 9 inches, is 350 tons.

2. Increased longitudinal strength, preventing damage to the decks, through buckling, for example.

3. Increased bale and grain capacity, by reason of the flat floor and the absence of beam knees between the transverse frames.

4. Increased local strength.

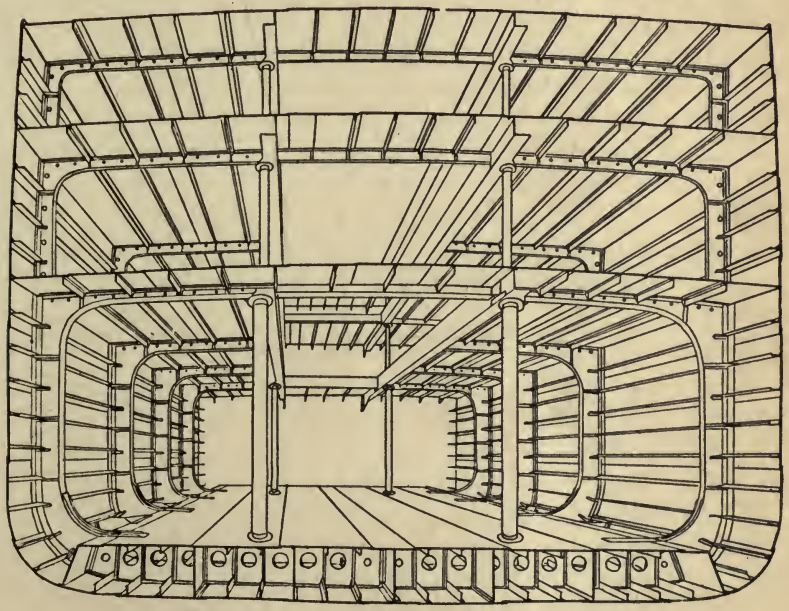

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FIG. 20.— LONGITUDINAL SYSTEM

5. Improved ventilation, the longitudinal through the transverse frames forming continuous air passages.

6. Lessening of vibration. The verification of this must depend upon the experience of the users. Undue vibration means increased wear and tear and cost of maintenance.

7. Ease of access to all parts of the structure, thus reducing costs of maintenance.

8. A stronger bottom, particularly valuable in trades where the vessel is compelled to take the ground when loading and discharging or entering and leaving port.

Aside from the questions of strength under actual usage and the relative cost of repairing damage which can be demonstrated only by experience, the following disadvantages of the Isherwood system appear:

1. A reduced capacity for cargoes having no short pieces to fill the space between the transverse sections, such as long timbers. In answer it is urged that a broader or longer vessel could be built with the same weight of steel as would be employed in a smaller vessel on the transverse type. If the same dead weight be retained in the larger vessel the ship can be of finer form, resulting in a larger ship, equally economically driven by the same power while having the same timber capacity as the smaller ship.

2. The longitudinals form ledges which retain a certain amount of cargo when unloading, e. g., coal and grain which must be swept off. But when stringers are used in the transverse system a similar objection presents itself, with the additional fact that the cleaning is more difficult. In a vessel of, say, 8000 tons dead weight the amount of coal lodging on longitudinals does not exceed 4 tons.

The remaining feature of the hull is the shell plating. This consists of a large number of steel plates of approximately rectangular shape arranged in longitudinal courses or strakes. The plates range from ¼ inch to 1 inch in thickness, varying with the location and the size of vessel. There are (1) flat plates which require little or no curvature, (2) rolled plates, which are found at the turn of the bilge, and (3) flanged or furnaced plates which require special shaping. The strake nearest the keel is called the *garboard strake,* and the highest complete strake the *sheer strake.* The plates are connected by rivets.

Terminology

This description of the principal parts of a vessel may be concluded by brief definitions of the terminology applied to various shapes, measurements, spaces, and superstructures.

1. Shapes.— The vessel for purposes of easy propulsion is not square at the bow and stern, but pointed, and a smooth curved line is formed from stem to stern, called the *water line.* Since the shape varies somewhat at different depths there is really a series of water lines. The bottom of the vessel is also rounded

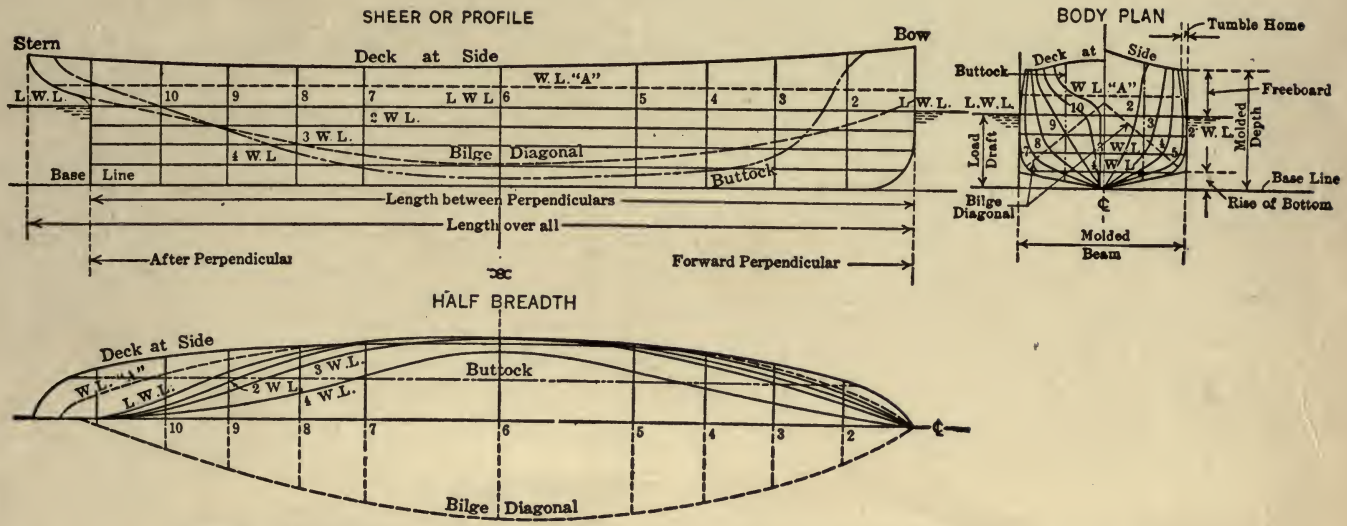

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FIG. 21.— PROFILE, HALF-BREADTH AND BODY PLAN

off and the curved portion between the bottom and sides is the *bilge* (see Figure 21). From the keel to the bilge the bottom rises or slants up somewhat and this is termed the *dead rise* (see Figure 21). The width of the vessel may be greater or less above the bilge than at the bilge. The amount of the decrease is called *tumble-home* and the amount of increase is the *flare* (Figure 21). *Camber* is the distance the center of the deck surface is above its sides (Figure 21). The decks also have a fore-and-aft curvature, being higher at the bow and stern, and this curvature is called the *sheer* (Figure 21).

2. Measurements.— The greatest length of the vessel is the *length over all* (Figure 21), but there is also the *length between perpendiculars* (Figure 21), which is the length usually agreed upon by shipowner and builder when contracting for a vessel and that usually understood when not otherwise specified. *Extreme breadth* is measured over the outside plating at the greatest breadth of the vessel. *Molded breadth* is measured over the frame at the greatest breadth of the vessel (Figure 21). *Molded depth* is the distance from the top of the upper-deck beams at the side of the vessel (Figure 21). In spar-decked and awning-decked vessels it is measured to the top of the main-deck beams at the side of the vessel. The *draft* is the vertical distance from the bottom of the keel to the water line at which the vessel is considered as floating (Figure 21). Measured forward it is the forward draft, and aft the after draft. The arithmetic average of the two is the *mean draft;* the difference between the two is the *trim* (Figure 21). Thus a vessel trimming by the bow has a greater forward than after draft; trimming by the stern denotes the reverse.

3. Spaces.— Trimming the ship is accomplished by watertight compartments at the extreme stem and stern just above the bottom, which are easily filled with or emptied of water, called the *forward* and *after peak tanks.* The greater part of the hull is occupied by the *holds* formed by bulkheads and running the width of the vessel, for the purpose of storing cargo. Rectangular openings in the deck, called *hatches,* furnish ingress and egress, covers being provided for the openings. Most of the remainder of the hull space is consumed by the *engine room, boiler room,* and *coal bunkers,* or, since oil has come into use, it might be more correct to say, generally, the propulsion space. Previous illustrations have shown the cellular character of the double bottom

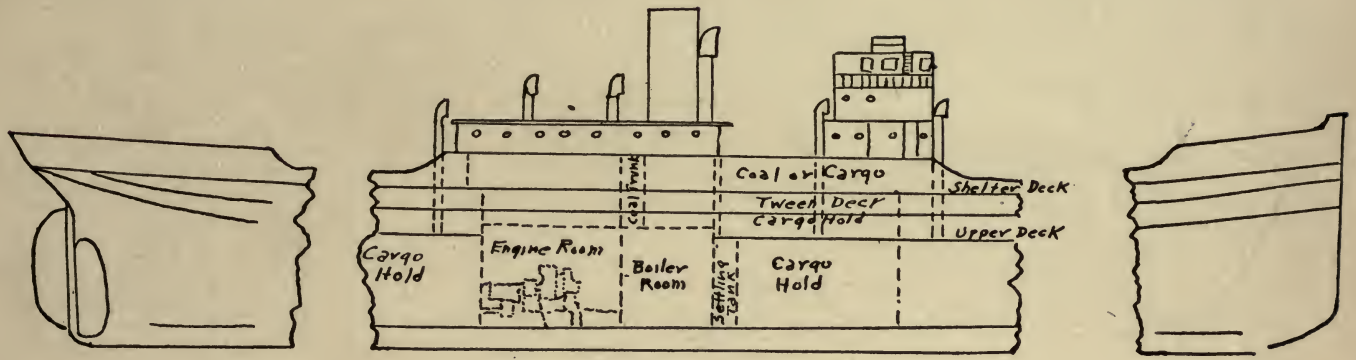

FIG. 22.— SPACES IN A CARGO VESSEL

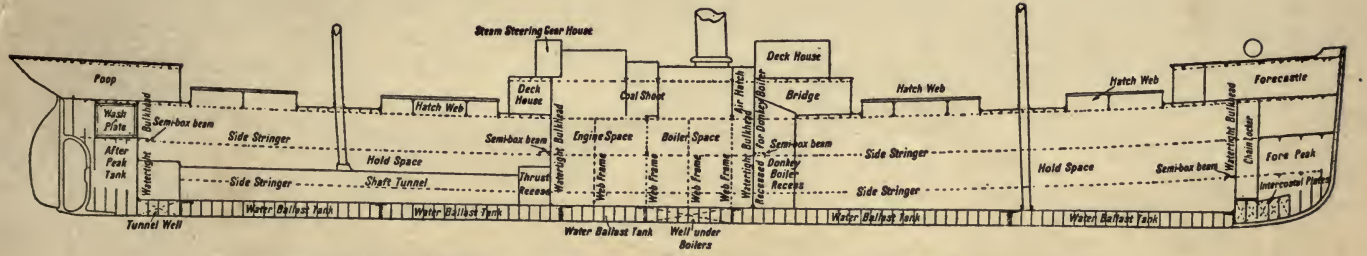

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FIG. 23

and these cells, made water-tight, may serve as tanks for water ballast to trim and steady the unladen ship or for feed water for boilers.

4. **Superstructures.**— The principal superstructures are the *forecastle* over the forward upper portion of the hull and sometimes used as quarters for the crew, the *bridge* or platform amidships for the controlling and steering apparatus, and the *poop* or after structure, often containing the steering gear.

Recapitulation

While nearly all vessels have distinctive features, there are many important characteristics common to all and serving similar purposes. A vessel hull consists of two parts, a shell and a frame. The frame consists of transverse and longitudinal members, the principal transverse members being the frames, reverse frames, floor plates, beams, pillars, and bulkheads. The principal longitudinal members are the keel, keelsons, and stringers. In the transverse system of construction the transverse frames are emphasized, and in the Isherwood system the longitudinal. Both have advantages and disadvantages, with the latter becoming increasingly popular. Various terms are used in describing the shape and measurement of a vessel and the principal spaces and superstructures have been briefly noted.

REFERENCES

1. Carmichael, A. W.: *Practical Ship Production.* McGraw-Hill Co., New York, 1919. Chap. III. (On the principal parts and methods of construction of steel ships, with clear explanations and good diagrams.)
2. Walton, Thomas: *Steel Ships.* Griffin & Co., London, 1918. Chap. V. (Brief summary of principal parts and methods of construction. More technical than the preceding.)
3. Walton, Thomas: *Know Your Own Ship.* Griffin & Co., London, 1917. Pp. 66–118.
4. Holms, A. C.: *Practical Shipbuilding.* Longmans, Green & Co., London, 1916. Vols. I and II. (Highly technical, with separate chapters devoted to individual structural features.)
5. Carmichael, A. W.: *Practical Ship Production.* New York, 1919. Pp. 31–50. (Form, dimensions and general arrangement of a vessel.)

6. Isherwood, J. W.: "Modern Shipbuilding and Economy in Material," paper before Society of Engineers, London, 1918. Published in *Fairplay,* London, May 30, 1918. (On advantages of the Isherwood construction.)
7. "The Isherwood System of Ship Construction," *Fairplay,* February 1, 1917. (On the advantages of the Isherwood construction. Less technical than the preceding.)
8. Carmichael, A. W.: *Shipbuilding for Beginners.* Published by Industrial Service Department, Emergency Fleet Corporation, Washington, 1918. (Brief and elementary description of the principal parts and the building of a vessel.)
9. Walton, Thomas: *Steel Ships.* Griffin & Co., London, 1918. Pp. 197–203. (Technical description and plans of the Isherwood system.)

CHAPTER IV

TYPES OF MERCHANT VESSELS

The object of the present chapter is to give some conception of the various kinds of merchant vessels, the influences which have developed the existing types, and the purposes and advantages of each. This is obviously a difficult task, seeing that almost every vessel has its individual peculiarities, some of which would never be reproduced except under the specific set of circumstances in existence at the time of construction. It is also difficult to indicate the advantages of even important features of construction in view of the fact that opinions may differ as to their desirability; what strongly appeals to one shipowner might be instantly rejected and condemned by another; one writer considers a ship a peculiar product which, once launched, seems to become an entity in itself, having an individuality not perceptible in any other product of human labor. All that is possible, therefore, is to attempt some system of classification which will segregate vessels into groups by concentrating attention upon some of their principal characteristics. In this process two viewpoints may be adopted. One may consider the vessel with certain construction features which make it mort adaptable to some sets of external conditions than others, implying an examination of its material, motive power, form, and design, capacity, etc.; or one may attempt a survey of the principal external factors which are conducive to various forms of construction and trace the results of these factors in existing types of vessels. The former method, which has been adopted here, works from the results to the causes; the latter from the causes to the results.

Vessels are constructed for a variety of purposes and with some of the resulting ships we are not concerned. They may be classified as follows:

I. Warships
   - A. Battleships
   - B. Cruisers
   - C. Gunboats

D. Torpedo craft
E. Mining and mine-destroying vessels
F. Submarines
G. Auxiliaries
1. Transports
2. Hospital ships
3. Colliers
4. Oil tankers
5. Supply ships
6. Ammunition ships
7. Repair ships
8. Patrol and Dispatch boats
9. Tugs, etc.

II. Merchant vessels
A. Passenger vessels
B. Cargo vessels
C. Combination passenger and cargo ships
D. Tugs
E. Unrigged craft
1. Barges
2. Scows
3. Lighters
4. Rafts

III. Whaling and fishing vessels

IV. Pleasure boats
A. Yachts
B. Gasoline launches
C. Houseboats

V. Vessels of investigation and preservation
A. Surveying vessels
B. Telegraph vessels
C. Salvage and wrecking vessels
D. Fire boats
E. Dredges

This list could be considerably expanded, but the only section of it with which this book is concerned is the second, dealing with merchant vessels.

The various types of merchant vessels will be discussed here with reference to the following characteristics:

1. Material of the hull
2. Form
3. Speed and character of service
4. Strength of construction and arrangement of decks
5. Motive power [1]

Material of the Hull

This phase of shipping has been rather fully discussed in the preceding chapter, wherein it was seen that while steel formed the bulk of the merchant marine, various materials were and are used in the construction of vessels, namely, wood, iron, steel, concrete.

1. **Wood.**— This was the earliest material in use and possesses the advantages of cheapness and workability, but the difficulty in some countries of procuring satisfactory lumber, the higher specific gravity of the wooden vessel as compared with steel, its weakness under stress, the limitation on its size, and its lower degree of safety caused a gradual diminution in its use. Wood became, therefore, principally a material devoted to the building of smaller vessels which did not warrant any considerable investment of capital, a product utilized for coastwise vessels engaged in uncertain and irregular trade on the American coasts, and occasionally the small vessel engaged in the lighter commerce with near-by foreign territory. The lumber trade of the Pacific Coast offered a profitable field for its employment for a considerable period, but even here the metal vessel became a strong competitor. It is still the principal material for unrigged craft. Occasionally periods arise when a shortage of tonnage, labor conditions, and the cost of construction play so important a part as to make the wooden ship profitable, but these conditions are merely temporary, and even in wooden vessels considerable metal is used for strengthening.

2. **Iron.**— Any kind of metal had the advantages enumerated, as compared with wood, and iron was naturally first used, but iron has become a subsidiary material in shipbuilding. It is inferior to steel in workability, strength, and uniformity of quality. Any former saving in cost was more than compensated for by the increased capacity of the steel vessel and recently even this difference in cost has disappeared.

[1] The discussion of motive power is postponed to Chapters VI and VII.

3. **Composite Vessels.**— This is a combination of a metal framework and a wooden shell. Its principal advantage is the immunity from fouling given by the copper sheathing, but this and other small advantages were an insufficient compensation for the greater costliness of the vessel and it became largely obsolete for merchant vessels.

4. **Steel.**— This is the material of primary importance, at the present time comprising over 90 per cent of the world's tonnage. It offers the advantages of speedy construction, great tensile strength, workability, uniform quality, great elasticity, and considerable saving in weight and capacity with reasonable cost. It is the basic material for the construction of all the large and fast passenger and freight vessels in the overseas trade, and even the slower cargo vessels are mainly so built. Only where cost of construction is a vital element and when steel is scarce can the other materials compete with it. It is interesting to observe the same progress from wood to steel in the production of aëroplanes, the all-metal plane being slowly developed.

5. **Concrete.**— During the World War, with the consequent demand for speedy production, the construction of concrete vesvels was undertaken. The end of the war made this largely a mere experiment, no experience being yet available to demonstrate the ability of this mixture to compete with other materials. If it possesses the necessary qualities for a shipbuilding material it offers the advantages of cheapness, speedy construction, and employment in shipbuilding of a new kind of labor; but its deficiencies are its liability to crack under stress, the excess weight of ordinary mixtures, and its porous nature. It may in future provide material for the construction of barges, scows, etc., for which it has occasionally been successfully used in the past, but will probably never in our time be an efficient competitor of the steel vessel in the general cargo or passenger trade.

Form of the Vessel

The form of a vessel is principally determined by the shape of the hull; it therefore is reflected in the various hull dimensions. On this basis a vast number of classes might be set up, corresponding to the innumerable combinations of various dimensions, but this obviously is not only an unending task but conveys no in-

formation. But it is just as plainly evident that there is a vast difference between the shape of the primitive log canoe and the form of a modern yacht. The principal elements of form are the length, beam, draft, and freeboard, and the various forms are best described by giving the relations between the vessel's several dimensions, such as the relations between length and beam, length and depth, etc.; and the accepted forms for expressing such relations, or ratios, are the following *coefficients:*

1. **Ratio of Length to Beam.**— The ratio of the length to the beam may be seen from a deck plan or from a comparison of longitudinal section with a transverse section, the former giving the length, and the latter the beam. In early modern vessels the tendency was to produce a low ratio of length to beam, that is to say, the beam was comparatively great as judged by our present standards. Thus, about the time of the clipper ship (1850) British vessels in the West Indian trade had a length approximately 4 times the breadth; the American builders increased the length to 6 and 7 times the breadth. The transatlantic liner developed from a vessel with a ratio of length to breadth of 8.3 to 1 with a ratio as great as 9.2, as in the *Campania* and *Aquitania.* A fast cargo carrier to-day may have a length approximately 8.5 times its breadth, while a 7500-ton vessel recently constructed for the United States Shipping Board was about 7.2 times as long as broad. The third dimension of depth, of course, should always be considered in relation to length and beam, but, other things being equal, the greater the ratio of length to beam the greater the speed of the vessel. Accordingly, we may expect to find that the slow cargo boat, the sailing vessel, the oil tanker, and the coal barge are comparatively broad, while the faster cargo liners and the speedy mail and passenger vessels are built on "finer" longitudinal lines.

2. **Ratio of Beam and Length to Draft.**— The beam is a most important element in the stability of the vessel; the greater the ratio of beam to draft, other things being equal, the greater the transverse stability. Where resistance to "heeling" is desirable, therefore, a high ratio of beam to draft is found. An early transatlantic steamer showed a ratio of 1.20, the *Lusitania* ratio was 1.40, a cargo vessel recently constructed for the United States Shipping Board had a ratio of 1.60, and a typical vessel in the

Australian trade a ratio of 1.70. Under English regulations the ratio of length to depth is an important one as concerns the freeboard and load line, the freeboard of a long vessel being greater in proportion to her depth than a small one, because of the consequent lower lifting power of individual waves. The load line determines the maximum carrying capacity consistent with safety, as defined by the rules, and the standard assumed is a length 12 times the depth.

3. **Block Coefficient of Fineness.**— This is one of the best indices of form inasmuch as it takes into account three dimensions. Suppose that the underwater form of a vessel be cut out of a block of wood. If the vessel be of very crude form nearly all of the block will be used and very little pared away. The ratio of the volume of the ship to the volume of the original block will be high, say, .90. On the other hand, if the vessel be of the more pleasing form of a yacht it will be necessary to cut away considerable wood to give the sharp bow, graceful curves and overhanging stern, resulting in a much lower ratio of the volume of the finished ship to the volume of the original block, say, .40. The diagram on page 54 illustrates the principle of the block coefficient of fineness, which is not only useful as an index of the form of the vessel but is also useful as a factor in calculating displacement tonnage. It is possible to arrange a series of classes of vessels according to coefficients of fineness, ranging from the very full to the very fine. In general, it may be noted that the block coefficient shows approximately the following variation:

Slow cargo vessels	.80
Ordinary cargo vessels	.75
Sailing vessels	.70
Mail and Passenger steamers	.60

The quality designated by a high coefficient is termed "fullness"; by a low coefficient, "fineness."

In other respects the form of vessels has tended to become more standardized. Thus, practically all cargo vessels and all large passenger steamers have the straight bow, as distinguished from the overhanging bow and extending bowsprit of the clipper ship and the schooner type. The latter is still found in the

schooners of the Pacific Coast and some sailing vessels (see illustration on page 5. The prow of the faster transatlantic steamers is sharper, however, than that of slower cargo carriers and the same is true of the stern. "Sheer," or fore-and-aft curvature of the deck, supplies lifting power by the distribution of reserve buoyancy. A flush-deck vessel without sheer or its equivalent, if loaded to the gunwales, would lack lifting power,

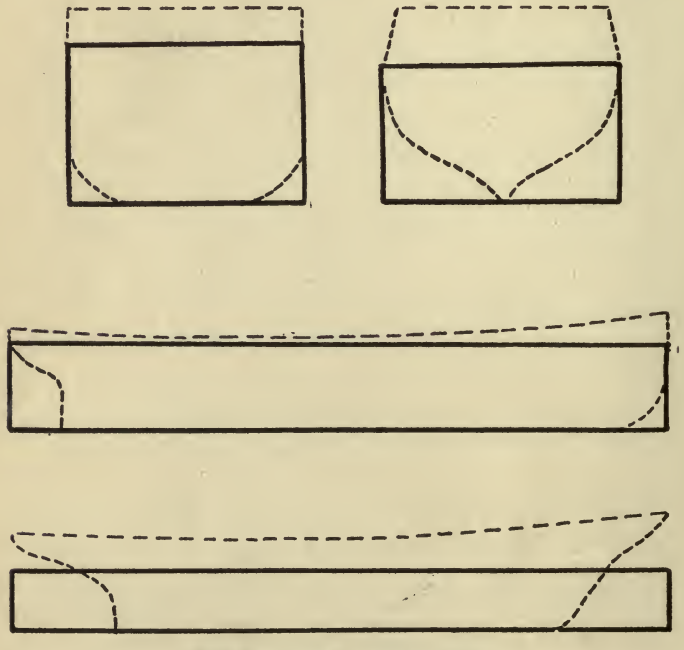

FIG. 24.— BLOCK COEFFICIENTS

and if nearly submerged would resemble a submarine. But although reserve buoyancy is valuable as resulting in less water on deck and greater protection to the crew, if ample reserve buoyancy can be provided other than by sheer, the greater depth at the ends provided by sheer may profitably be added uniformly the length of the ship. In some vessels of recent construction sheer has been eliminated and in order to supply the reserve buoyancy which would have been furnished by sheer the vessel is equipped with a very high poop and forecastle extending a considerable length at each end.

Speed and Character of Service

It is necessary to distinguish between vessels on the basis of the character of the service rendered, for this gives rise to legal, structural, and economic differences. A vessel may be either (1) a common carrier, or one which offers itself as ready to transport goods for any who may offer them, the space being available and the terms mutually satisfactory, or (2) a private carrier. As a private carrier it may operate in either of two ways, (a) transporting goods for the same person who owns the vessel, or (b) being hired out to another under contract, in which case the owner of the vessel, if the agreement gives the charterer the full capacity of the ship, becomes a bailee transporting as a private carrier. In the former class of common carriers are the so-called "line" vessels and in the latter class the "tramp" vessel and the industrial carrier. It will be advisable first to define and indicate the principal characteristics of the tramp, liner, and the industrial carrier and then proceed to a comparison of the line vessel and the tramp in greater detail and from various aspects, indicating the services rendered by each.

1. **The Tramp Vessel.**— After the private carrier the vessel engaged in what is now called the tramp service is the earliest type known. When trade was irregular and unsystematized a voyage was more in the nature of a venture than of a trip. The owners expected the voyage to be largely governed by the conditions found to exist at the various ports of call, and the regions visited might be radically changed by circumstances unforeseen at the time of departure. The owner of the vessel frequently owned all or a part of the cargo. An important individual on every ship was the supercargo, who at that time attended to the ship's business, delivered cargo, arranged sales of goods shipped at a venture, purchased goods for the owner's account, or contracted for homeward space. The success of the voyage depended upon the business ability of the captain and supercargo, these functions being often united. A voyage therefore was a most indefinite undertaking, as different from the regular lines of to-day as a peddler is from a high-class commercial salesman with a definite route.

These vessels were the precursors of the modern tramp, a ship with no fixed sailing dates, no constant termini and no definite

route. It is available for almost any form of cargo and varies its operations in accordance with the profits to be made, being usually designed for general serviceability and lacking the specialized features which will be seen later to fit vessels for particular services. Nevertheless, of recent years numerous vessels designed especially for carrying coal, ore, grain, oil, and frozen meat have been built. Such a vessel may reach its home port only at intervals of several years. Thus, a vessel of this type might sail from New York with a cargo of grain for London, from London take a general cargo to Australia, thence proceed with a cargo of ore to Europe. It might there be chartered to transport a cargo of iron and steel products to South America and there take on nitrates for the United States, thus finally again reaching this country after being in nearly all parts of the world. The typical vessel in this business is of about 5000 tons gross, 3000 tons net, with a speed of around 10 knots and a dead-weight capacity of 7800 tons. The tendency is to increase the dead-weight capacity of vessels at present constructed.

2. **The Line Vessel.**— In contrast with the tramp, the line vessel derives its name from its operation along definite routes. It has fixed terminals and established sailing dates, which are rarely deviated from, its regularity being one of its principal recommendations. Thus, instead of seeking cargo, as the tramp, the cargo must seek it and even though cargo be lacking it must maintain its schedule. The line service may be provided by vessels chartered for the purpose, so that a ship may change its status from tramp to liner. On the other hand, vessels built primarily for line traffic are generally of superior character and speed and are consequently seldom utilized as tramps until unsuitable for the original purpose. Line vessels may be subdivided into:

(a) *Express Steamers.*— These are floating palaces, designed primarily for the accommodation of passengers, with all modern luxuries and exceptional speed. As an illustration the *Mauretania* may be cited — length, 787 feet; breadth molded, 88 feet; gross tonnage, 31,550; dead-weight capacity, 1500 tons; speed, 25 knots. These vessels have been most fully developed on the North Atlantic route, due to the overwhelming importance of the passenger traffic. The freight capacity is small.

(b) *High-Speed Passenger Steamers.*— These are slightly inferior in speed but scarcely in comfort to the immense express

liners, though they lack the ornateness and some of the luxury of the larger vessels. The *Campania, Lucania, Celtic*, and *Cedric* might be cited as illustrations of Cunard and White Star liners of this type. They are around 20,000 gross tons with a speed of from 16 to 20 knots.

(c) *Combination Vessels.*— These vary all the way from those built primarily for passenger accommodation to those intended mainly for freight. They are principally the outgrowth of conditions in the North Atlantic route. Owing to the passenger traffic, a combination steamer can be operated more economically and cheaply for freight than a freight ship. In fact the cargo space in these combination vessels is frequently excessive as compared with the goods offered, so that commodities are carried at far cheaper rates than would otherwise be possible. The *George Washington* may be cited as an illustration of this type of vessel. She has a speed of around 18 knots and a gross register of 18,000 tons. Another illustration of the use of these vessels is found in the trade between the United Kingdom and the Far East, a typical vessel being 550 feet in length and of 12,000 tons gross register.

(d) *Cargo Liners.*— There are many lines which are primarily or entirely freight lines. The South American trade furnishes an excellent illustration of this type of vessel, practically all the lines being freight carriers exclusively. Their vessels are built to attain a moderate speed with considerable cargo capacity. They carry tools, scientific instruments, cotton goods, flour, and hardware to South America, and bring in return coffee, rubber, cocoa, etc. The service furnished is equivalent in regularity to the high-class passenger lines but at half the speed.

3. **Industrial Carriers.**— With the tendency toward integration of industry and the progress of large corporations toward ownership of all the essential factors entering into the preparation and marketing of their products it was inevitable that industrial and commercial companies should come to own and operate the vessels which carry their products. In some cases this result is attained by building and owning fleets, and in others by chartering or hiring vessels from others. Regular lines are thereby established by these concerns for the carriage of their products and frequently in addition they will carry commodities for others, becoming common carriers to this extent. The designation "industrial

carrier " is used here, however, to designate vessels and lines which were primarily established for the convenience or profit of a specific industrial or commercial concern in the carriage of the commodities in which it deals. The articles in which this policy has been more highly developed are coal, iron, fruit, fish, oil, asphalt, and lumber. We have, for example, lines of the United States Steel Corporation, operated through the United States Steel Products Company, serving between New York and Brazil and New York and Vancouver; the operation of vessels in the coal trade by the Dominion Coal Company, and by many eastern railroads; Standard Oil Company supplies and products are collected and distributed in many parts of the world by more than 60 tank vessels; the commercial firm of Grace & Company operated a line to the west coast of South America; many lumber concerns of the Pacific Coast own and operate fleets of steam schooners and sailing vessels in the domestic trade and some in the foreign trade; the United Fruit Company owns and operates over 40 vessels aggregating several hundred thousand tons, engaged in conveying tropical fruits from Jamaica, Guatemala, Honduras, Costa Rica, Panama, and Colombia. In the domestic trade this policy is also apparent. One might cite the illustration of the Great Lakes, where consolidations of coal and ore carriers, stock ownership by industrial concerns, arrangement of chartering facilities, and interrelations between industrial corporations and carriers have made the latter practically an integral part of the former. The advantages of private ownership of the means of communication have principally been the following: (1) The development of vessels particularly suited to the individual trade, as for instance, the fruit trade. Most of the companies first chartered vessels from other owners and after a period of development began to build vessels specially adapted to their businesses. (2) The acquisition of a service which exactly met the needs of the corporation as regards regularity and frequency. (3) Independence of the common-carrier transportation facilities, which evidence has shown often exerted considerable influence over producers and traders in certain areas. (4) A reduction of the costs of transportation by eliminating the carrier's profit. (5) An increased domination of the particular industry as far as water transportation facilities could contribute to this end.

From the standpoint of the public, the benefits of this develop-

ment have been (1) specialized equipment, resulting in better handling and quality of products; (2) growth of transportation facilities in regions otherwise poorly served; (3) increased regularity of service; (4) greater actual and potential competition by American concerns with foreign producers; (5) possible reduction in cost of product by economical management of the carrying trade.

Comparison of Line and Tramp Services.—

(a) *Standardization.*— From the character of the services, the products carried, and the condition under which business is carried on, it has necessarily resulted that in the line traffic the effects of specialization have been most keenly felt, while in the tramp traffic generally standardization has been an important factor. In the line traffic a carrier serves continuously the same ports and carries approximately the same kinds of product, so that it is possible fairly closely to adapt the type of the vessel to the character of the trade, resulting, for example, in the development of refrigerating apparatus in the trade between England and Australia and in the trade between the west and east coasts of the United States; in the immense combination liner in the Atlantic trade; in vessels specially adapted to carrying sugar in the American-Hawaiian trade. Since the tramp must accommodate itself to the business which is offered and must carry a variety of products, few owners care to incorporate features which might at times be a detriment rather than a profit. This results in a tendency toward a generally useful vessel and, with the inducement to copy the economical and successful vessel, in a tendency toward standardization, which reduces construction costs but likewise individuality.

(b) *Types of Cargo.*— While the line vessel will carry cargo of all descriptions, since its rates are usually higher it will naturally tend to transport goods of relatively high value as compared with their bulk, which can afford to pay the higher rates. The line furnishes speedier transportation, a quality which costs, and consequently low-grade goods are not likely to seek this means of transportation. Grain, cotton, foodstuffs, and metal manufactures are frequently carried in considerable quantities, however. The tramp vessel, on the other hand, will mainly carry goods which do not require speedy delivery, which commercial arrangements do not require to be delivered regularly, which are susceptible of

loading and unloading without exceptional facilities, and which are comparatively of great bulk and low value. Thus we find that tramps are extensively employed in the grain trade of the United States, Argentina, and India, in carrying nitrate from Chile, in transporting lumber on the Pacific Coast, in bringing ore from Spain, Cuba, and Chile, in carrying sugar from Porto Rico, and occasionally coffee from Brazil, in carrying fibers from the Far East, and coal from Great Britain and South Africa. Occasionally, however, tramps may be chartered for the carriage of steel products or machinery by large corporations. Occasionally also, as described later, they are loaded with small lots of cargo belonging to various owners, but they commonly carry goods moving in full vessel loads.

(c) *Contracts.*— The contract for the carriage of goods is called "a contract of affreightment." The carriage is performed in either of two ways: (1) The owner may operate a line, state his terms and carry goods for any who offer them, in which case the essential document embodying the agreement between the carrier and the shipper is a bill of lading. (2) The owner may hire out his ship's services to a person who has goods of his own to transport. The agreement in this case is essentially a lease, with many important special features, called a charter party. The bill of lading is therefore usually the important document in line traffic and the charter party in tramp vessel operation. This is not the place, however, for a discussion of the provisions and uses of these documents.[2]

(d) *Methods of Operations.*— The tramp vessel is frequently owned by an individual or a firm, and in some cases is even divided into shares and owned by a number of individuals, while the line traffic has practically become the property of large corporations, which alone can afford the necessarily large investment of capital. The tramp vessel may be operated in any of the following ways:

Carriage of its owner's goods
Carriage for hire
  Leased to a line for operation in line service
  Chartered to a shipper for carriage of full cargoes
    On a time charter
    On a voyage charter
  Placed on the berth

[2] For such a discussion see G. G. Huebner, *Ocean Steamship Traffic Management,* D. Appleton & Co., N. Y., 1920, Chaps. XI, XII, and XIII.

The latter method means that an agent announces that he will sail the vessel on a given voyage "if sufficient cargo is offered." If enough goods are obtained on provisional contracts the engagement is made final and the goods are loaded. The cargo therefore consists of a number of relatively small consignments usually, and the rates are made on the charter basis. Similar goods in similar amounts may be carried for very different rates of freight, the agent getting what he can for the various shipments. The line vessel, on the other hand, must maintain regular and sufficient sailings and fairly stable rates. The sailing takes place when announced, whether warranted by the cargo offered or not. Offices and agents are maintained for the transaction of business, while the tramp business is mainly carried on through ship brokers, who furnish vessels and seek cargoes for vessels, receiving a percentage of the freight for their services. The innumerable brokers are all connected by the telegraph and telephone network of the world, so that vessels and cargoes may proceed from place to place in accordance with the supply and demand for each.

The organization of the line traffic has proceeded even further than the individual line or individual steamship company. In their efforts to influence service, rates, competition, relations at ports, etc., the lines have in many cases entered into associations or agreements, designed to fix common rates, apportion the traffic between otherwise competing lines, retain business of shippers, maintain regular services, and promote coöperative issuance of tariffs.[3]

(e) *Types of Vessels Employed.*— There is, of course, no definite line of distinction between the line vessel and the tramp as far as type is concerned, for the tramp is frequently chartered for line service, though the liner rarely becomes a tramp. The following table will be interesting, however, as showing the differences between the typical vessels of each kind.

The following table shows that the line vessel may range all the way from a 5000- or 6000-ton cargo liner with a speed of 10 knots to an express liner designed especially for passengers, with a gross register tonnage of 60,000 and a speed of 30 knots. The large

[3] Methods of operation and organization of lines and tramps are extensively described in G. G. Huebner, *Ocean Steamship Traffic Management*, D. Appleton & Co., New York, 1920, Chap. V.

	Cargo	Gross tons	Speed (knots)
LINERS			
Express liners	Passengers	50,000–60,000	25–30
High speed	Passengers or goods	20,000–30,000	20–25
Combination	Passengers and goods	15,000–30,000	10–20
Cargo	Goods	8,000–15,000	10–15
TRAMPS			
High speed	Goods	2,000–15,000	10–13
Low speed	Goods	2,000–15,000	8–10
INDUSTRIAL CARRIERS			
General cargo	Goods	2,000–10,000	8–10
Specialized equipment	Goods — occasionally passengers	4,000–15,000	10–15

tramp vessel is 375 feet in length, has a gross registered tonnage of about 7500 tons and attains a speed of from 8 to 10 knots. The liner serves the important ports of the world, where channels and harbors are made for its convenience, while the tramp must accommodate its draft to the terminals it visits. It is designed to afford the largest possible cargo capacity in proportion to its internal volume. Thus, a tramp of only 2500 tons gross may have a dead-weight cargo capacity of 6000 tons, while a transatlantic palace of 30,000 tons may afford space for only several thousand tons of cargo. The tramp is designed for general utility with the factor of economy always an important one. It will therefore be built for carrying capacity rather than for speed, and the construction cost is usually reduced to the minimum consistent with its purposes. In form the tramp will be full, having a block coefficient of around 80 per cent, as compared with the 60 per cent of a passenger liner. The high coefficient is obtained through the blunt bow, flat bottom, and straight sides of the tramp, replacing the sharper bow, curved bottom, and finer underwater lines of the liner. Naturally the cargo liner approaches the form of the tramp. It is difficult to particularize further on the type of the tramp steamer, owing to the variety of cargo carried. In the main, goods are bulky, but they are not necessarily of great density. The tramp cargo may vary from wool with a weight of 15 pounds per cubic foot to coal at 94 or chalk at 156 pounds per cubic foot. But in order to be of the greatest earning power it is

necessary that the vessel be fully occupied when loaded to the maximum draft. For cargoes of great density this requires a vessel of at least moderately strong construction. In Great Britain the freeboard is dependent upon structural conditions and in order to obtain the smallest freeboard and consequent large loading capacity the strongest construction is required. In the trades where cargoes of this nature are the rule, therefore, the full-scantling vessel is employed, while vessels of lighter construction, such as spar-decked and raised quarter-decked vessels are used for general cargo. These types are discussed in the next section. Where relatively little cargo and many passengers are carried the vessel may be of very light construction toward the upper deck. Such a vessel would have great freeboard, and the upper deck would consequently be more free from water.

(f) *Relative Economy.*— In this connection it may be said in general that the tramp obtains economy at the expense of speed, while the liner's advantage must be compensated for by increased expenditures in many directions. From one-quarter to one-half the working expenses of a vessel consist of fuel cost, and the familiar economic "law of diminishing returns" is also apparent in the shipping business. Beyond a certain point the extra speed attained is not proportionate to the additional fuel required. Thus, an immense steamer reaching a speed of 25 knots does so at the expense of twenty times the coal required for a 10-knot freighter. The coal consumed by a large transatlantic liner in one voyage from New York to Liverpool would be sufficient for ten such voyages by a slow cargo carrier. The liner therefore pays heavily for the privilege of making more voyages annually and collecting higher freight rates. In addition, greater fuel space and engine space must be provided at the expense of productive space, the schedule must be maintained regardless of freight earned, the construction cost of vessels is higher and the management expenses are great, for advertising is employed to create traffic, offices must be maintained to handle the business, and the staff must be sufficient to care for the largest volume of business, though part of it may be idle in duller times. Special equipment must often be provided and operated in specific trades, such as refrigeration facilities. The economies of the tramp vessel may be briefly summarized as economies of (1) construction, (2) navigation, and (3) management.

(g) *Rates.*— Aside from the fact that the tramp rates are in the long run lower than the line rates, their outstanding feature is a relatively greater fluctuation. Thus, charter rates are principally dependent upon the supply of and demand for tonnage; the years 1900 and 1912, and the years of the World War were years of prosperity and high rates for the vessel owner, while 1896, 1904, and 1908 were comparatively poor years. So great is this fluctuation in rates that a middleman in the form of a speculator has stepped into the business, who stands ready to make contracts for steamer space in advance. The extreme fluctuations of charter rates as compared with line rates are in part due to the lack of organization of the business. Thus the charter-party terms may vary somewhat, the local conditions may not be in accordance with general conditions due to a local excess or deficit in vessel tonnage and the effects are felt of unrestrained competition, which is considerably diminished in the line traffic by the existence of the associations and agreements previously referred to. Some efforts at tramp combination have been made but the nature of the business makes it difficult to see how they can be permanently successful. There is some interrelation between line and charter rates owing to the potential competition of the tramp vessel, but investigation has shown that this as a regulatory factor has been considerably exaggerated. The present contrast shows how distinct the two classes of service are in practice.

(h) *Earnings.*— A discussion of shipping profits would take us too far into the field of finance. It is sufficient here to say that profits in general have always been very variable. This is particularly true of the tramp companies, which suffer heavily in periods of depression. The traffic of the lines is relatively more stable and their financial policy is better adapted usually to the variations in business, reserve funds for contingencies being built up. *Fairplay,* an English shipping journal, reproduced a table of cargo-boat earnings for ten years, the average ten-year percentage dividend on capital being 4.7 per cent. The annual percentage varied, however, from 1.9 per cent in 1909 to 12.6 per cent in 1913. During the same period the dividend record of the Hamburg-American Line, one of the largest, varied from 0 to 11 per cent.

(i) *Extent of Tonnage.*— It is estimated that the tramp vessels are 25 times as numerous as the line vessels. But the latter naturally make a better showing in gross tonnage because of their larger individual size, and approximately 40 per cent of the total tonnage is estimated to be line tonnage and 60 per cent tramp. Of the tramp tonnage Great Britain probably owns at least two-thirds. The possession of the tramp tonnage is divided among possibly 40 times as many owners as the line tonnage, nearly all of which is found in the hands of about 100 large companies.

CHAPTER V

TYPES OF MERCHANT VESSELS (*Continued*)

Construction and Arrangement of Decks

Relation of the Load Line to Type of Vessel.—It is advisable to introduce the subject of types of construction by a brief explanation of "load line" and "freeboard," with which it is closely connected. The load line is the "line of surface of the water on a ship when loaded to the maximum allowance." Freeboard is the "vertical distance from the upper water-tight deck to the water line when the ship is fully loaded," or the "height of the upper deck above water, taken amidships at the gunwale." It is evident that the weight of cargo influencing the load line and freeboard and the structural strength of the vessel bear some relation to each other. There is obviously a great difference between a steam yacht carrying comparatively little weight and even requiring permanent ballast adequately to immerse it and a slow tramp steamer weighted down with cargo of great density. In the latter case there immediately arises the question of whether there are sufficient structural strength and seaworthy qualities. It would be absurd to construct all vessels of equal strength, for if one is intended to carry a cargo of coal and the other a cargo of wool, either one would be too weak for its purpose or the other excessively strong. The relation between load line and construction may be stated from two viewpoints with the same import: (1) There is for every vessel a certain load line (though admittedly difficult to fix) which marks a limit not to be exceeded if one is to avoid (*a*) straining the structure, or (*b*) losing the necessary weatherly qualities. (2) Assuming a certain required load line or capacity, a vessel is built with a certain strength and seaworthiness. For the present purpose weatherly qualities may be described as follows:

a. Protection from sweeping waves by adequate reserve buoyancy, which is principally obtained by having the side a

sufficient distance out of water, or freeboard. This is necessary to render the deck safe for operation, prevent the gear, ventilators, hatch covers, etc., from being swept away, promote the comfort of passengers, make bulkhead divisions effective, prevent water from penetrating below, etc.

b. Wave-riding qualities, or proper distribution of reserve buoyancy, which is obtained by sheer or superstructures. The bow and stern must encounter approaching and overtaking waves, and here buoyancy is most effective. A flush-deck vessel without sheer or superstructures would be inferior in weatherly qualities. This reserve buoyancy, "liveliness," or "lifting power," must be measured relatively by the ratio of the volume of reserve buoyancy to the vessel's weight or displacement.

The load line is of great importance in two ways: from the standpoint of safety, which is apparent, and from the commercial standpoint. A vessel's earning power depends upon its ability to carry cargo, and if the freeboard required is too great the owner is necessarily discriminated against. Great Britain attempted to furnish the necessary safety by requiring all British merchant vessels over 80 tons to have an official load line assigned to them beyond which they could not be loaded, and tried to maintain equity by having such load lines assigned by expert calculation of "classification societies."[1] No such requirement exists in the United States, for, although its necessity is recognized, the load line is "obtained by rules largely artificial in character," and with many different types of vessel engaged in a variety of trades

[1] In 1876 it was enacted in Parliament that vessels should have a freeboard mark painted on the side (since known as a Plimsoll mark), but since it was furnished by owners themselves it was no guarantee of safety. It was frequently arrived at by a rough rule which took no account of the vessel's proportions or form. In 1882 Lloyd's published a set of freeboard tables based on experience and consultation, and one year later a Board of Trade committee investigated the subject and practically endorsed these tables. In 1890 an official mark was made compulsory for all British vessels. In 1906 the freeboards assigned were found to be excessive, enabling foreigners safely to get deeper loading than British vessels, and the tables were revised, among other things reducing the freeboard for vessels with superstructures and protected deck openings. In 1913 an investigation by the Board of Trade resulted in general approval of the existing requirements, with some modifications to remove the preferential treatment of special newer types of vessels. The freeboard is based principally upon (1) a standard strength, (2) a standard ratio of length and depth, (3) depth, (4) coefficient of fineness, (5) a standard sheer, (6) a standard camber, and (7) superstructures.

discrimination between vessels and between nationalities is feared. The latter might be avoided by international action. The British marks have accordingly been the principal standard used in overseas traffic.

Classification by Structural Features

In the following classification it will be noticed that vessels are primarily segregated into three groups on the basis of structural features: (1) The full-scantling vessel, (2) the spar-deck vessel, (3) the awning deck vessel.[2]

Each group is separately discussed with its modifications and customary supplementary features, such as superstructures, deck erections, etc. These three types for steel vessels are mentioned in the tables and rules fixed by the British Parliament, from which all assignments for British load-line certificates are made. While some varieties of these three types have very evident peculiarities, others are difficult to distinguish by casual inspection. This may be demonstrated by an attempt to estimate from a photograph the capacity, gross tonnage, or number of decks of a vessel. The observer may take to be similar two vessels, one of which is five times the size of the other, and the number of decks is equally difficult to determine; for this reason photographs are only occasionally employed here as illustrations. The load line often is a better indication of the main class of a vessel than its appearance. The statements subsequently made that certain types employ lighter forms of construction do not imply structural weakness. All of these types are equally strong, presumably, in proportion to their dead weight, which is the only fair basis of comparison of a number of types designed with very different purposes in view.

It may further be said that since the primary object of a vessel is to earn fares and freight, success must be judged by the ability fully to load the vessel. A vessel designed as a combination

[2] Some writers prefer to consider vessels as developing, from a logical standpoint, from a flush-deck vessel without superstructure to one with superstructure, shade-deck vessel, awning-deck vessel, etc., up to the full-scantling vessel. This method has some advantages as regards facility of explanation, but fails to emphasize certain structural differences. The second deck from the bottom is always known as the main deck and the expression "upper" is sometimes used as denoting the topmost deck, but technically refers to the deck above the main deck.

freight and passenger ship must necessarily be at a disadvantage in carrying only heavy goods, because it necessarily performs the journey with unoccupied space for which no return is had, and the empty space is even subject to taxation. The object of the passenger vessel is to carry a maximum number of passengers with comfort to them. For the cargo boat the following are essential:

1. A low registered tonnage compared with capacity.
2. Ample space available for water ballast.
3. Large hatchways.
4. Holds as free as possible from obstructions.
5. In most cases, economical operation at fair speed.

1. **Full-Scantling Vessel.**— This is a vessel of the strongest construction, in which the structural strength is maintained up to the upper deck. It may have one, two, three, or more decks, and a depth of 12 feet or 40 feet, but this structural characteristic must be present to bring it within the full-scantling class. An important part of the carrying trade is concerned with commodities of great density compared with their bulk, such as ore, coal, rails, machinery, and iron and steel products. By loading the average vessel with goods of this nature, she would easily be brought down to minimum freeboard and maximum draft long before her available cargo space was fully occupied. For work of this nature, therefore, a vessel should have great carrying power and strength with the minimum volume or space, requirements which are most nearly fulfilled by the full-scantling type. Likewise, in some trades it is customary to carry considerable cargo on deck, and consequently the necessary structural support must be furnished. Lumber might be cited as a cargo so carried.

(a) *Three-Deck Vessel.*— Many full-scantling vessels have three decks and some have more. The following midship section illustrates a three-deck vessel and it will be noticed that the decks from the keel up are called the lower, main, and upper decks.

The upper deck is regarded as the strength deck up to which the full structural strength must be maintained, for, the vessel being almost wholly immersed when fully laden, any damage sustained up to and including that deck jeopardizes its safety. The expression "three-deck vessel" arose from the requirement

of a classification society that vessels over a certain depth should have three decks in the absence of other equivalent strength. Some vessels are so constructed, and formerly it was common to

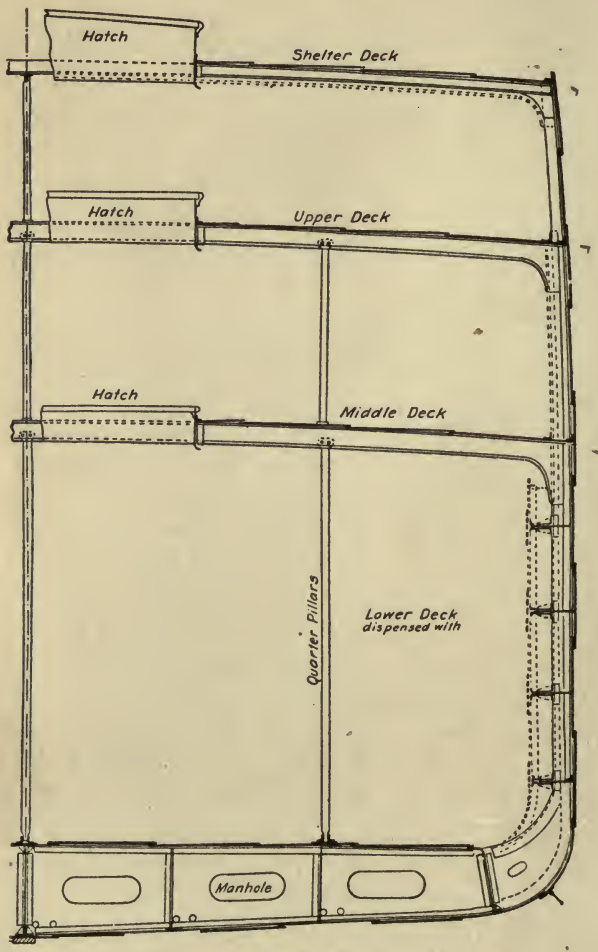

FIG. 25.— THREE-DECK VESSEL

have two complete decks and a tier of hold beams below, but now a vessel of this character often has only one laid deck, and need not possess three tiers of beams. The lowest tier may be dispensed with by the deep framing and web framing described in a former chapter, or both lower tiers may be replaced by one of

widely-spaced extra-strength beams and strengthened framing. Where only one steel deck is required, the wooden middle deck may be eliminated by the allowance of a small additional freeboard and increased framing strength. In sum and substance the expression "three-deck vessel" refers either to one of three decks

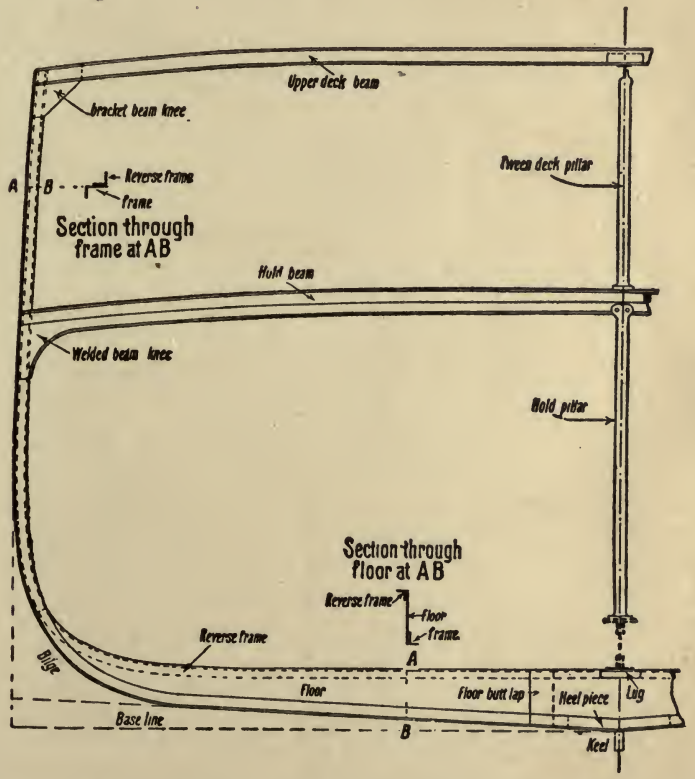

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FIG. 26.— TWO-DECK VESSEL

or with sufficient depth for three decks. The illustration above shows a three-deck vessel in which the lower deck is dispensed with.

The three-deck vessel is the strongest vessel built and consequently has a minimum freeboard, maximum immersion, and greatest displacement and carrying power. It is available for the carriage of commodities of great weight as compared with size, and for trades in which deck cargoes are an important feature.

The early types of three-deck vessels were deep and narrow because of an impression that breadth contributed exceptionally great resistance to propulsion. Within recent years the breadth has been considerably increased, however, with a corresponding gain in stability and safety. Additional strength above the standard results is no decrease of freeboard, since this is already minimum, but such reduction may be obtained by the addition of superstructures. As a vessel grows older or depreciates in strength, it may be necessary to increase the freeboard, in connection with which stability and the vessel's proportions must also be considered. In larger vessels it is customary to have at least a substantial bridge covering half the length amidships for the protection of the engines.

(b) Two-Deck Vessel.— This is a smaller edition of the three-deck vessel and by Lloyd's rules has a depth of less than 24 feet from the top of the keel to the top of the beam at the center. As in the three-deck vessel, two actual decks need not exist provided there is sufficient space for them. These vessels frequently have superstructures and erections on deck, as described hereafter, for which considerable allowance in freeboard is made. This type of vessel is employed in the general carrying trade where cargoes of great density are frequently offered for shipment, but where size of vessel does not contribute so greatly to economical operation. Figure 26 is a midship section of a two-deck vessel.

(c) *One-Deck Vessel.*— In structure, this is similar to the three- and two-deck vessels, the full structural strength being maintained to the upper deck. By Lloyd's rules, it is a vessel with a depth of less than 15 feet 6 inches from the top of the keel to the top of the beam at the center. The typical modern vessel with one deck is approximately 380 feet in length, 50 feet in breadth, and 28 feet in depth, with a gross tonnage of about 5000 tons and from 6000 to 7000 tons dead-weight capacity at a draft of 24 feet. If fitted with widely-spaced pillars, this vessel is available for cargoes of any ordinary description, whether units of great volume or homogeneous cargo, such as grain, in bulk. The expression one-deck vessel is frequently applied to a vessel with sufficient space for two decks.

(d) *Raised-Quarterdeck Vessel.*— This is essentially a vessel of the full-scantling type inasmuch as the structural strength

is maintained up to the upper deck, no such erection as a raised quarterdeck ever being built on vessels of the spar- or awning-deck type. The raised quarterdeck is a feature customary in one-deck and two-deck vessels and seldom found in the three-deck vessel. There is an essential difference between this vessel and the light spar- and awning-deck types described hereafter. The raised quarterdeck really constitutes an increased depth over the rear portion of the length, and the after part of the vessel is structurally equivalent to the extra depth so created. This vessel might, therefore, be considered as composed of parts of two vessels united in one, one of said vessels being from 3 to 6 feet

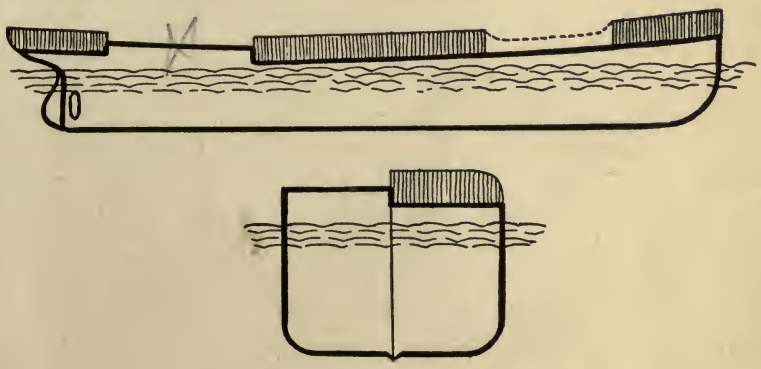

FIG. 27.— RAISED QUARTERDECK VESSEL

greater in depth than the other. The quarterdeck must be carefully and strongly joined to the upper deck, as this line of division would otherwise be a place of great strain. The average extent of the rise of the quarterdeck over the main deck is about 4 feet.

Figures 27 and 28 make clear the nature of the raised-quarterdeck erection, if an integral part of the hull can be called such.

The raised quarterdeck type originated by reason of difficulties created by the placing of engines and boilers. If placed at either bow or stern, the vessel would necessarily trim by the bow or stern respectively when not loaded, although a satisfactory condition was maintained with cargo on board. On the other hand, placing boilers and engines amidships caused difficulty in trimming when the vessel was loaded. The shaft tunnel occupied a relatively

large space in the after portion of the hull, and since this part of the hull was necessarily built on finer lines than the fore part, the vessel trimmed by the head when loaded with homogeneous cargo of some density. There was no trouble where heavy cargo could be used in the after holds for trimming and where the vessel as a whole carried a very light cargo, the ballast tanks being sufficient properly to trim the vessel. In other cases, however, great difficulty was experienced and this was remedied by increasing the depth of the hold space above the engines through

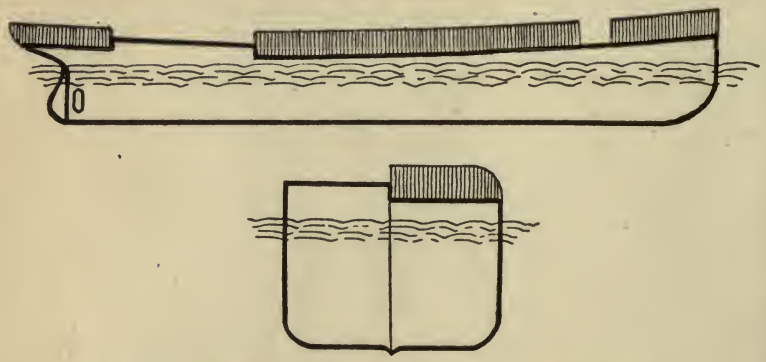

FIG. 28.— RAISED QUARTERDECK WITH EXTENDED BRIDGE

the medium of raising the quarterdeck. This type of vessel was used to a considerable extent in the Atlantic cargo trade when provided with strong deck erections and no passages in the bridge-house. In brief it furnished the following advantages:

1. A better trimmed vessel when loaded
2. Additional capacity
3. Considerable buoyancy credit which was about equivalent to that given for a long poop, 7 feet high

It is customary to protect the engines by a bridge because of the small freeboard, and this bridge was occasionally extended almost to the forecastle, creating a between-decks space which was available for the carriage of light goods, but the increase in registered tonnage was relatively heavy for this space as compared with the extra freight which could be earned by it. Registered tonnage has always had great influence on design because of its use as a basis for taxation. This type was due principally to

artificial legislative difficulties and not to commercial requirements. The illustration on page 28 shows the bridge extended forward to create this modified quarterdeck vessel.

The following illustration shows a shorter raised quarterdeck which was sometimes built. It is necessary to distinguish between this short raised quarterdeck and the superstructure erected at the stern of a vessel known as the poop. The former is an integral part of the whole and has no deck laid below it, while the latter is simply a structure built upon the deck.

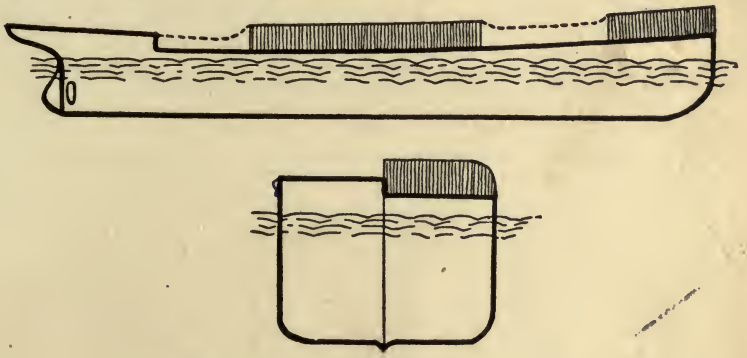

FIG. 29.— SHORT RAISED QUARTERDECK

(e) *Shelter-Deck Vessel.*— The expression "shelter deck" has been applied in several senses and its meaning consequently confused, but its original import was a structure built upon the upper deck and extending the full length of the vessel, either wholly or to some degree unenclosed and designed merely to afford some shelter from the elements. The term is also employed to designate the deck above the upper deck, with or without tonnage openings, in a four-deck vessel. This expression is most commonly used, however, to designate a three-deck vessel with a complete erection fore and aft on the upper deck, entirely closed from the sea with the exception of tonnage openings which may resemble hatchways or may be wide enough to extend to the sides of the vessel. The shelter deck is usually of steel or iron and with the recent tendency to increase the strength of structure, this type of vessel has come to resemble an awning-deck vessel in construction, the shelter deck being more and more built into the hull. The following is an illustration of the shelter-deck type.

This type of vessel was originally due to the development of the

cattle trade in which considerable general cargo was carried, and unenclosed space in the shelter deck was available for live stock. This space was exempted from the gross tonnage of the vessel and consequently paid no dues while it contributed considerable credit for reserve buoyancy in the determination of freeboard. The net result was an increased capacity on a small tonnage, although the shelter-deck space was gradually more and more securely enclosed and became available for the carriage of light cargo. In a vessel with four decks, this shelter deck also affords a between-decks space available for passengers and miscellaneous cargo.

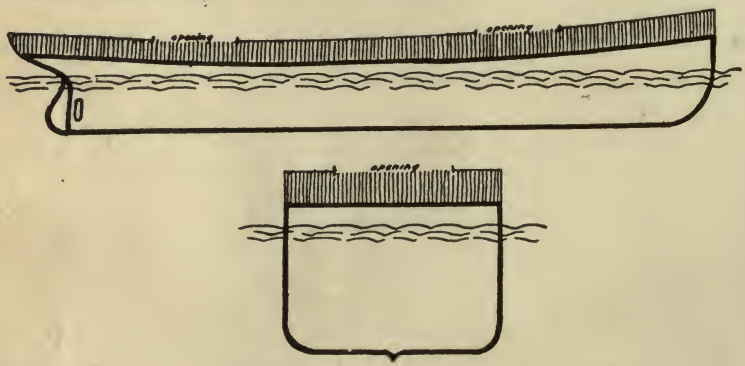

FIG. 30.—SHELTER-DECK VESSEL

(f) *Well-Deck Vessel.*— Such vessels are so called because the space between the bridge and forecastle, being enclosed on four sides by the bridge, forecastle, and sides of the vessel, forms a well which, in a heavy sea, is frequently washed by the waves. The type may be divided into two classes. In the first place, the raised-quarterdeck type of vessel resulted in the existence of a well of this nature as illustrated by the diagrams preceding. Secondly, the combination of a long poop, bridge, and topgallant forecastle, forms a similar well, as illustrated by the following diagram (Figure 32).

The well is left open and uncovered (1) because if covered in it would be measured and yet for trimming reasons would be unavailable for general cargo, and (2) because the vessel would be swept by waves which otherwise fall in the well and wash out through scuppers. The long full poop extended to the bridge house was intended to serve in a lesser degree the same purpose

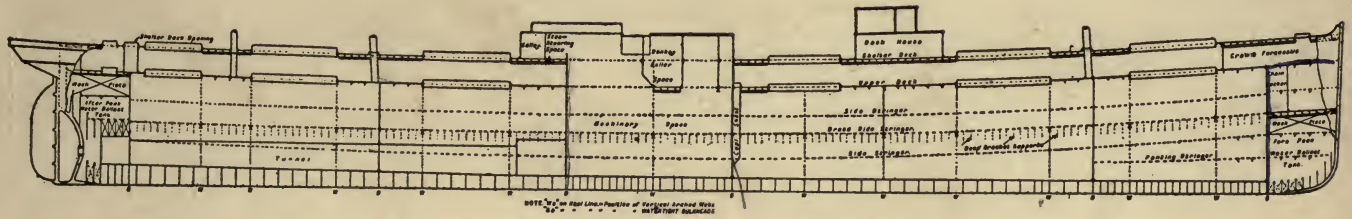

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FIG. 31.— SHELTER DECK VESSEL

as a raised quarterdeck, but it is useful only for light cargo.

This type was formerly very popular. In 1875, 30 per cent of the total tonnage built in the United Kingdom was of the well-deck type and 31 per cent three-deck vessels; while in 1890,

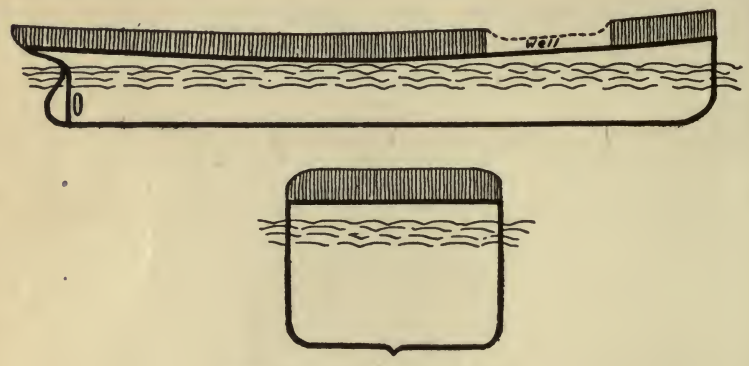

FIG. 32.— WELL-DECK VESSEL

these two types formed respectively 43 per cent and 18 per cent of the total tonnage constructed. This characteristic gave to the vessel the following advantages:

1. A single-deck vessel of small registered tonnage could be cheaply built and operated.
2. Such a vessel could be well filled with homogeneous cargo, such as grain, and could also carry dead weight in a favorable position relative to the centers of gravity.
3. It had a high range of stability, great safety, and was easy to keep in trim either loaded or light.
4. The well prevented the waves from sweeping the decks.

In recent years, this vessel has been largely superseded by other types, with a tendency to emphasize flush-deck vessels with superstructures.

(g) *Full-Scantling Vessel with Superstructures.*— Any vessel may be equipped with superstructures built upon the upper deck, the three most common being the forecastle, bridge, and poop. Such superstructures are very valuable as affording reserve buoyancy and this at the places where most valuable. In a later chapter it will be shown that a system has been devised for giving credit in freeboard for such erections in proportion to their

efficiency. The following diagram shows a vessel equipped with these customary superstructures.

Without considerable freeboard, a flush-deck vessel would be constantly swept by the seas. The waves which are met head on would wash over the bows, interfering with the operation of the vessel, washing away deck fittings, and finding their way below. To obviate this the sides of the vessels were raised at the bow

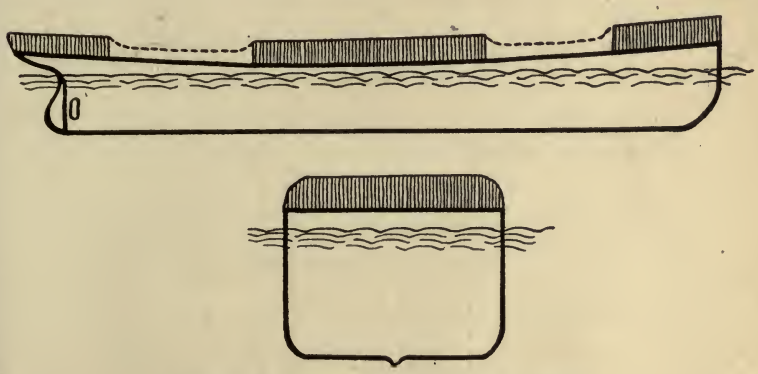

FIG. 33.—VESSEL WITH SUPERSTRUCTURES

and the space so formed closed in by a bulkhead, the whole being rounded off to a hood shape which was termed a monkey forecastle. Subsequently the forecastle developed in height and length and afforded accommodations for the crew. In addition, a platform was afforded which was advantageous in working the anchor. This enlarged structure is termed a topgallant forecastle. Similar uncomfortable results were occasioned by following seas washing over the stern, and since protection was desirable for the hand steering wheel near the stern, this portion of the vessel was hooded over in a similar manner forming a short poop. This erection also developed in size until it was used for the accommodation of officers, and finally, by extension into a long poop, might even be utilized for cargo. The bridge was originally simply an erection in the center of the vessel for the use of navigating officers and the lookout, being of very light construction, but later it was practically made an integral part of the structure and served as a protection to the engines, formerly only covered by a glazed skylight. In recent years, the bridge has been extended in width to the sides of the vessel.

(h) *Shade-Deck Vessel.*— The shade-deck vessel has a superstructure built upon the full length of the upper deck, of light structure and open at the sides. It frequently consists merely of light deck beams supported on round iron stanchions and thus is far from being an integral part of the hull. It is frequently found upon large passenger vessels but gives no additional reserve buoyancy. This deck superseded the original unstrengthened awning deck. An illustration is given below.

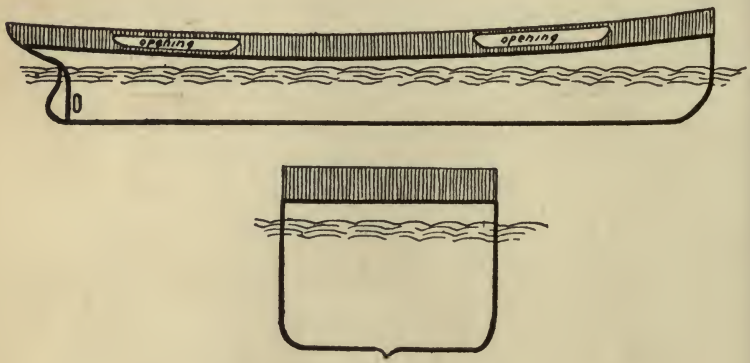

FIG. 34.— SHADE-DECK VESSEL

A shade deck is intended only as a shelter for passengers and to provide a promenade. It is frequently found in the largest cargo and intermediate steamers where it does not reduce seaworthiness and affords a covered shelter in combination with small registered tonnage.

(i) *Whaleback Steamer.*— This vessel, as indicated by the name, has a design above water bearing crude resemblance in shape to a whale. It is distinctly an American invention, and a vessel of this type first crossed the Atlantic in 1891. The object was to provide a seagoing vessel with absolutely clear decks, so that there were no deck erections to be carried away by the sea. The peculiar, rounded form of the deck was expected to break the force of the sea and allow it to escape easily over the sides. It had a spoon-shaped bow and in two respects resembles the turret steamer, next to be described, viz., in the absence of fore-and-aft sheer, and a rounded gunwale. The engines are located at the stern of the vessel behind a water-tight bulkhead. The hatchways are simply holes in the deck with no

coamings and closed by plates bolted through the deck. The frontispiece and following diagram give a better conception of this vessel than any description.

This type of vessel was designed to carry the largest amount of cargo with the lowest registered tonnage, an object which was fully realized. It has chiefly been utilized for the carriage of grain, coal, and ore, many of these vessels being in operation on the Great Lakes and the Pacific Coast and a few having been transferred to the Atlantic Coast coal trade. Ore cargoes can

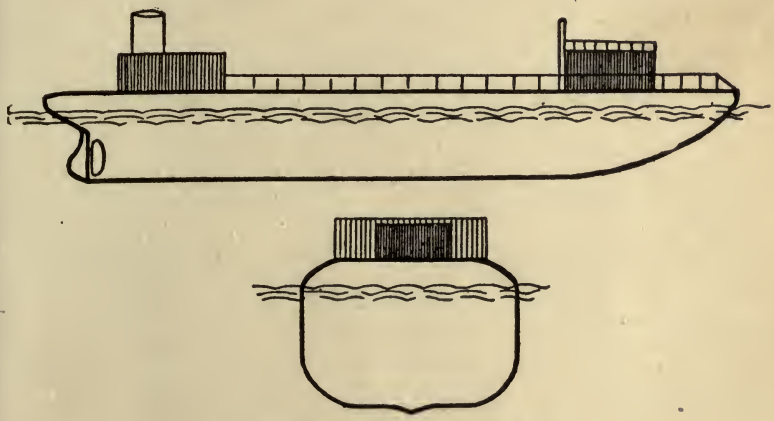

FIG. 35.— WHALEBACK STEAMER

be stowed to great advantage in the cylindrical holds and with the hatches bolted down these vessels are exceptionally seaworthy. They have been increased gradually to 450 feet in length, 50 feet in breadth and 27 feet in depth, with a carrying capacity of approximately 9000 tons at a draft of 20 feet. They exhibited, however, several disadvantages. Great difficulty has been experienced in getting about the decks in bad weather; the only facilities being a gangway above the deck, separated at intervals by turrets. Secondly, the spoon-shaped bow and the form of the bottom from the stem for some distance aft makes the hull peculiarly subject to the pounding of the waves in a head sea. These vessels have never had any extensive use as passenger carriers, although the *Christopher Columbus* was constructed for this purpose and carried passengers to and from the World's Fair on the Great Lakes with a record of carrying 1,700,000 during the period. This work

involved a very great deal of embarkation and disembarkation and it was found possible to unload as many as one thousand passengers a minute. On this vessel, five steel turrets above the main deck separated a promenade, upper, and hurricane deck.

(j) *Turret-Deck Vessel.*— This vessel was in all probability an outgrowth of the whaleback steamer and has been very successful, particularly in England, where one shipyard has for long periods built this type almost exclusively. It is similar to the

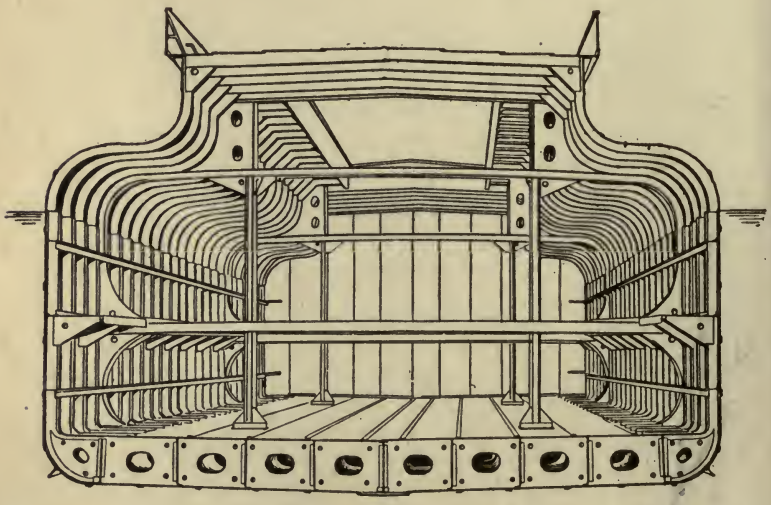

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FIG. 36.— TURRET-DECK VESSEL

whaleback steamer in two respects, viz., the absence of fore-and-aft sheer and the rounded gunwale, and in other respects radically different. The form of the vessel below water is the same as that of an ordinary vessel and on the main deck or harbor deck a turret erection extends continuously from stem to stern. The sides of this turret bend into the harbor deck and the harbor deck into the vertical sides of the vessel by well-rounded curves. By reason of the increased strength given to the deck by curved sides and large angle girders, the hold pillars can be unusually widely spaced with the resulting advantage in stowage facilities. The latest type of turret vessel has approximately a 30-foot depth without hold beams, harbor deck beams,

or pillars, leaving the hold spaces entirely clear. All deck openings and erections are on the turret deck, which is the working deck while at sea. In the later vessels, numerous spaces are provided in the double bottom tanks for water ballast, and to compensate for the absence of sheer, there is a topgallant forecastle. Figures 36 and 37 are illustrations of the latest type of turret-deck steamer.

This form of vessel is particularly valuable for the coal, ore and timber trades and for trades in which long voyages must be

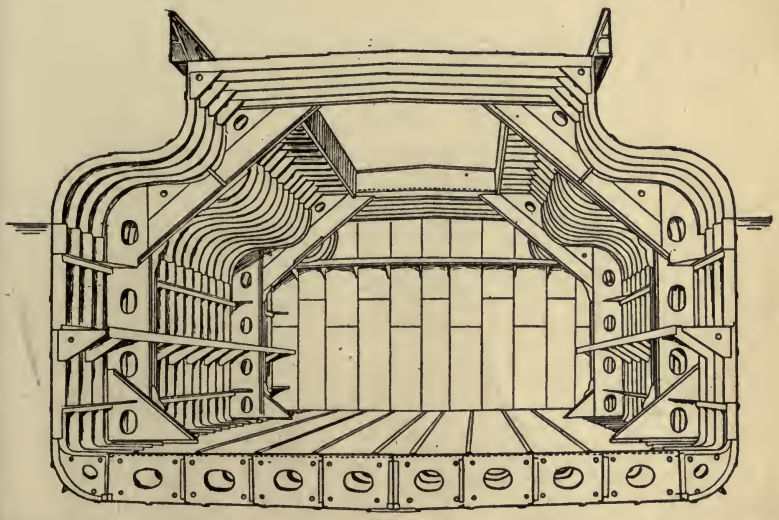

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FIG. 37.— TURRET-DECK VESSEL

made in ballast. It is a remarkably good dead-weight carrier and the harbor deck can be used for the carriage of lumber, long iron girders, etc. These vessels have also been successfully built to carry light case cargo and some have been also constructed with between-decks for general cargo. In addition, the type possesses the following advantages:

1. It is exceptionally strong in construction and the turret gives extra longitudinal strength.

2. An absolutely clear hold enables advantageous stowage of large bales, case cargoes, and bulk cargoes.

3. A large amount of water-ballast space is advantageous on voyages where a portion of the journey must be performed empty.

4. There is no opportunity for seas finding lodgment on the turret or harbor decks.

5. Credit for reserve buoyancy is obtained on a basis of 70 per cent of the turret volume.

6. As every part of the structure contributes to the strength and there are no breaks in the continuity of the decks, there is a considerable saving in weight as compared with ordinary boats of the same dimensions.

7. The turret deck is from 10 to 12 feet above the load line, furnishing protection to the important parts of the vessel, pre-

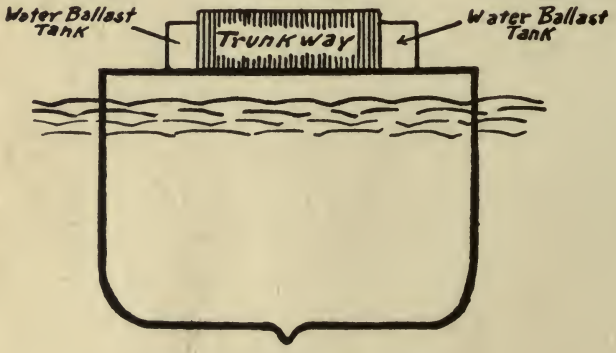

FIG. 38.— TRUNK-DECK VESSEL

venting the seas from breaking over the ship and keeping the navigating platform clear of water.

8. The harbor deck is said to tend to reduce rolling.

9. Under the Suez Canal measurement rules, the vessel has the benefit of having the turret considered as an erection with the consequent measurement of only little more than half the cubic capacity.

10. Whereas in the ordinary vessel homogeneous cargoes tend to subside and consequently shift, the turret forms a feeder from which the cargo can shift into the lower holds, keeping them completely full. The shifting in the turret is of small consequence as regards stability.

11. The depth of the turret may be increased aft to enable the vessel to trim by the stern in the same manner as a raised quarter-deck vessel.

12. Cargo can be shot into the holds without trimming.

(k) *Trunk-Deck Vessel.*— This vessel, like the turret-deck vessel, is similar to the ordinary vessel up to the gunwale, but on the main deck a trunk erection extends from poop to bridge and from bridge to forecastle, the height of which is approximately 7 feet. Unlike superstructures this forms a continuous erection. This trunk erection is approximately half the beam of the vessel in width, the space below the trunk is entirely open down to the lower hold, and all hatchways, ventilators, and deck

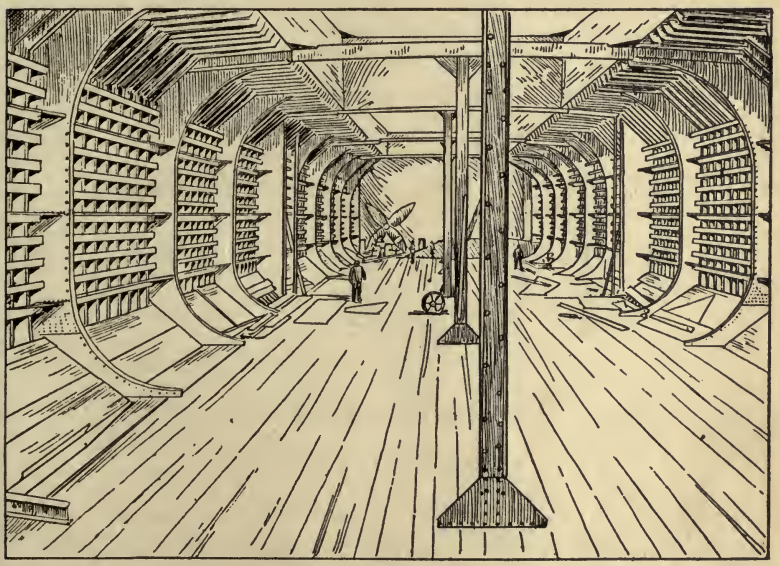

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FIG. 39.— TRUNK-DECK VESSEL

openings are on the trunk deck or superstructure. Of recent years great development has taken place in the trunk steamer. It is now usually fitted with a trunk extending the full length of the vessel, with the height varying from 7 to 10 feet, and the breadth of from 50 to 75 per cent of the beam of the vessel. The trunk is thus much wider than formerly and the vessel is now usually fitted with a forecastle and sometimes a full poop but no bridge. If desirable, the deck may be carried through under the trunk and the latter made an unenclosed and consequently an unmeasured space. Vessels are also frequently furnished with water-ballast tanks at the sides of the trunk. The

hold space is entirely clear except for widely spaced hold pillars. Figures 38 and 39 are illustrations of trunk-deck vessels, one showing a vessel with water-ballast tanks at the sides.

Like the turret-deck vessel this ship was designed for large dead-weight and cubic capacity on a small net registered tonnage and may be used for general cargoes or for coal and ore. It has a similar advantage as regards free-hold space, and water-ballast tanks at the side increase the immersion when light and promote the efficiency of the propeller and helm, giving an easier motion in a sea way. As in the case of the turret, the trunk

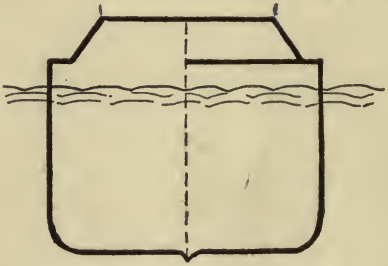

FIG. 40.— SELF-TRIMMING VESSEL

is an excellent feeder to the main holds, contributing to the satisfactory trimming of the vessel. The main deck outside of the trunk is well fitted for carrying timber, cattle or other deck cargoes. This design has sometimes been employed for carrying oil in bulk.

(1) *Self-trimming Vessel.*— This is an ordinary vessel with an erection about five feet high, extending the length of the ship and having a top breadth of about half the beam of the ship, which forms a navigating deck. The sides of the erection slope from the navigating deck to within two feet of the gunwale, in order to increase the self-trimming capacity of the ship. All hatches, funnels, and deck openings are on the navigation deck and hold beams are dispensed with. The erection has free communication with the hold for trimming purposes, the self-trimming idea being the distinctive feature of the vessel. As the sloping side of the navigating deck offers insufficient protection from in-rushing seas, a closed iron bulwark is fitted to the navigation deck which keeps this deck dry and affords protection in navigation. The above is an illustration of this type of vessel.

(m) *Cantilever Vessel.*— This is a vessel very similar in some respects to the self-trimming vessel but with important structural differences. An ordinary vessel of its type would belong to the three-deck type. Several feet before reaching the deck, however, the frames bend inward and are projected diagonally forward to the base of a top fore-and-aft girder, extending continuously all along the length. There is formed, therefore, on each side a tri-

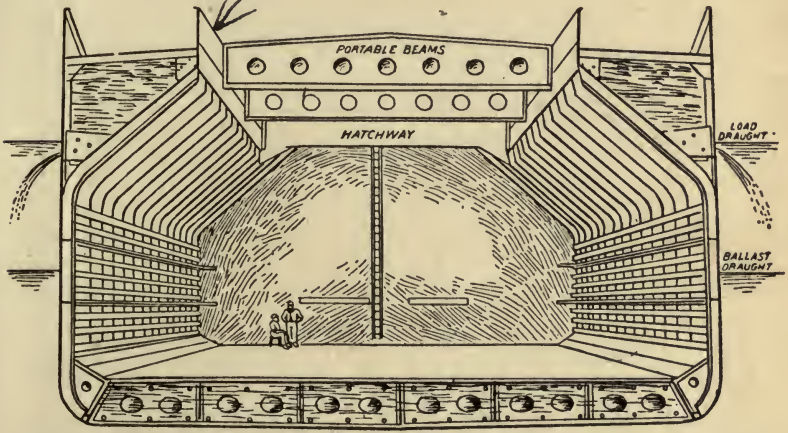

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FIG. 41.— CANTILEVER VESSEL

angular space, two sides of which are formed by the shell and the deck plating, and the third side is furnished by the plating over the bent-in frames. The word cantilever is a combination of "cant" meaning angle and the word "lever." In this vessel, the deck is supported by a leverage obtained from the angle to the frame, hence the name. Figures 41 and 42 are illustrations of this type of vessel.

This vessel possesses the following advantages:

1. An absolutely clear hold space.

2. Greatly increased water-ballast space, sometimes amounting to nearly one-third of the total dead weight.

3. The water ballast is distributed over the length of the ship instead of being concentrated in the center as where midship deep tanks are used. While some space is thereby lost, this is the very space which is most difficult to fill with bulk cargoes in ordinary vessels.

4. No trimming expenses.
5. The construction permits of long, broad hatches.
6. The full width deck area is preserved for deck cargoes.

(n) *Corrugated Vessel.*— This is an ordinary tramp steamer in dimensions and engine power with two corrugations running along each side between bilge and water line, and extending from the turn of the bow to the turn of the quarter. These do not project much but through their effect on the stream and wave action

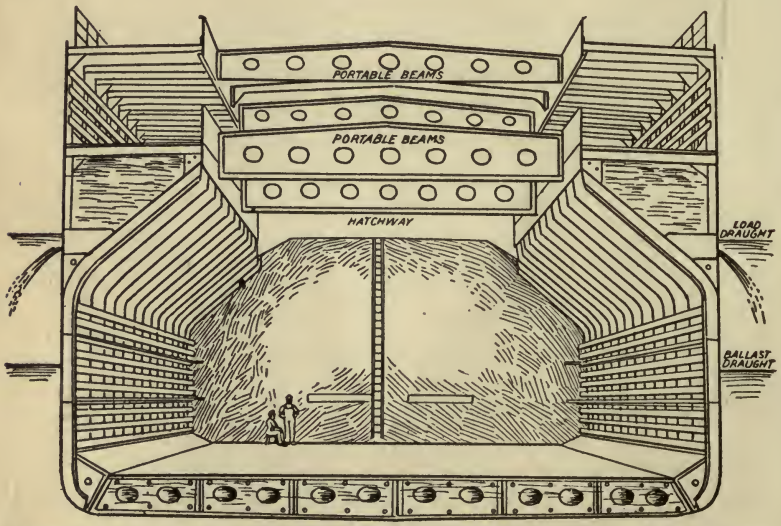

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FIG. 42.— CANTILEVER VESSEL

around and under the vessel, they are said to save otherwise wasted energy and to have the effect of bilge keels in making the vessel steadier. The space for bulk cargo is greater than in the ordinary vessel by the space of the corrugation but the tonnage remains unaltered, and a faster speed is said to be attained with a smaller coal consumption.

(o) *Tank Vessel.*— These vessels have been constructed in various ways, all designed to economize the carriage of fluid cargoes, such as petroleum products and molasses. The earliest variety was an ordinary cargo vessel with tanks fitted into the holds; a cheap method of production which entailed considerable loss of space, and increased weight. In modern practice the

sides and deck of the vessel form integral portions of the tank and the vessel's bulkheads form the other two sides of the tank. In other words, instead of a vessel containing one or more tanks, the vessel itself is a large subdivided tank. A newer type of oil-carrying vessel consists of a hull of ordinary construction fitted with cylindrical tanks, and is thus a reversion to the earlier form. This is a cheaper method of construction, but its principal claim to distinction is that by the removal of the tanks the vessel is converted into an ordinary carrier. The cylindrical tanks, however, cause the loss of some oil-carrying space.

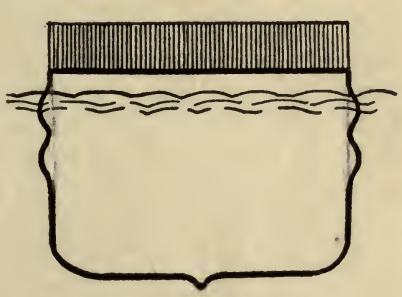

FIG. 43.— CORRUGATED VESSEL

In two-deck vessels the second deck forms the crown of the oil tanks, and in vessels of sufficient depth to require three tiers of beams the lower tier is usually dispensed with. Oil vessels have been built with an inner skin but apparently with little advantage, as the space formed by the outer and inner shell serves to harbor gases.

The engines may be located either amidships or at the stern, but the latter location is preferred because of more complete isolation from the cargo and consequently greater safety. In a vessel with engines situated aft the compartment abaft of the collision bulkhead is used for general cargo. The protection for the engines is obtained by a long poop and in the Atlantic trade this frequently extends as far forward as the deck house, amidships. The crew is housed in a topgallant forecastle. These vessels may be equipped with spar or shelter decks, but the latter has no tonnage openings and is a shelter deck in name only.

It is necessary to mention some of the characteristics of oil as a cargo, since they illustrate the distinctive features of the tank vessel. (1) The gases from petroleum products, especially crude

oil, become highly explosive when brought in contact with the atmosphere. Consequently the tanks must be carefully constructed to prevent leakage and a system provided for drawing off the gases emitted, which are heavier than the atmosphere. They are usually blown out of the oil tanks by steam injections. The engines must be effectively isolated from the cargo. (2) Oil is subject to expansion and contraction with increases and decreases of temperature. An increase of 20 degrees Fahrenheit causes an increase in the volume of oil of approximately 1 per cent, and since variations of from 40 to 60 degrees are quite common on ordinary voyages it is evident that some means must be provided for absorbing this expansion. Cold, on the other hand, causes contraction and creates empty space in the tank, which is conducive to rolling. Tank vessels are, therefore, provided with expansion tanks or trunkways fitted between decks, extending fore-and-aft over the main hold tanks, which usually hold about 15 per cent of the vessel's oil cargo and which serve as space for expansion or as feeders to counteract contraction and keep the main holds full. (3) While the ordinary cargo is supported by the transverse and longitudinal framing, the oil cargo, like all fluids, exerts pressure in all directions, extending in some vessels to the outside shell. Oil-tightness and strength are, therefore, important characteristics of the tank vessel, and for it the Isherwood system has been extensively used because of the reduction in weight and extra longitudinal strength thereby attained. (4) A fluid cargo is inert and accentuates the rolling of the vessel, besides exerting heavy pressure with the motions of the ship. A longitudinal bulkhead is, therefore, provided extending all fore-and-aft and dividing the cargo into two parts, so as to minimize this effect. (5) The process of loading and unloading must be carefully performed because any listing of the vessel will be increased by the shifting of the fluid cargo to the lowered side. It is apparent that full tanks are an important consideration in connection with safety, and that stability is a prime factor in this type of ship.

The early method of transporting oil was in cases and barrels. The bulk system, however, permits of faster loading and discharging, so that an amount of petroleum requiring otherwise 4 or 5 days for loading or unloading (say 1700 tons) can be handled in bulk in 6 hours. Likewise, there is great economy in

space, resulting in increased earning power. A ton of oil in barrels occupied approximately 80 cubic feet of space, while a ton of the ordinary type of cargo required to bring a three-deck vessel down to her load draft does not require more than 50 feet, in-

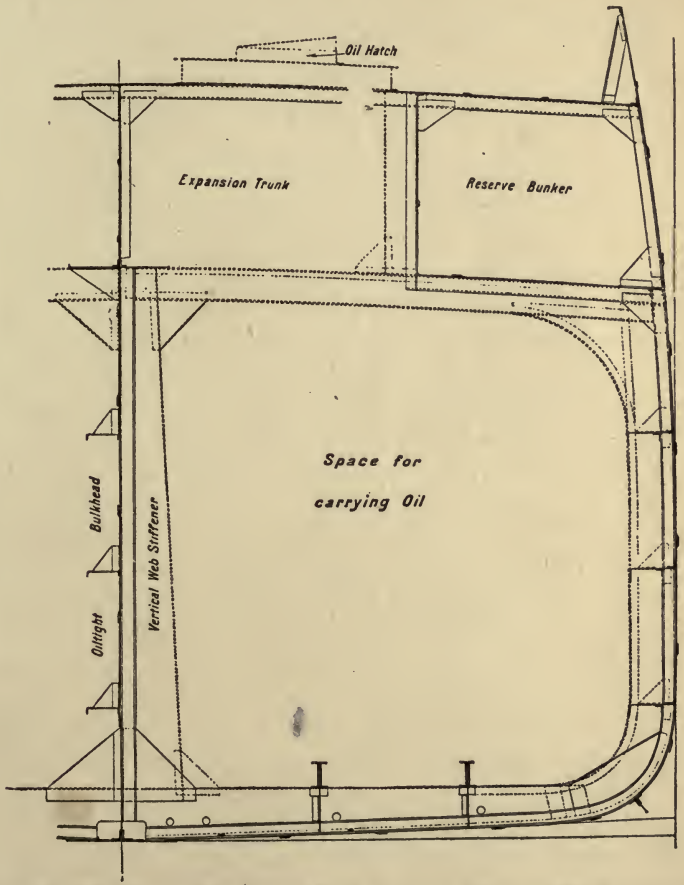

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FIG. 44.— TANK VESSEL

dicating the wastefulness of the barrel method. In bulk a ton requires no more than 40 cubic feet. There are now over 300 large steamers and 50 sailing vessels engaged in carrying oil in bulk. Above is shown an illustration of a typical tank vessel.

(p) *Refrigerator Vessel.*— While the processes used are essentially the same, we must distinguish between the refrigeration facilities in ocean passenger steamers, which are confined to supplying an insulated chamber for fresh meat and supplies consumed on the voyage, and the more extensive appliances in refrigerating steamers carrying cargoes of frozen or chilled meats.

Two systems are employed in the cargo trade. The freezing

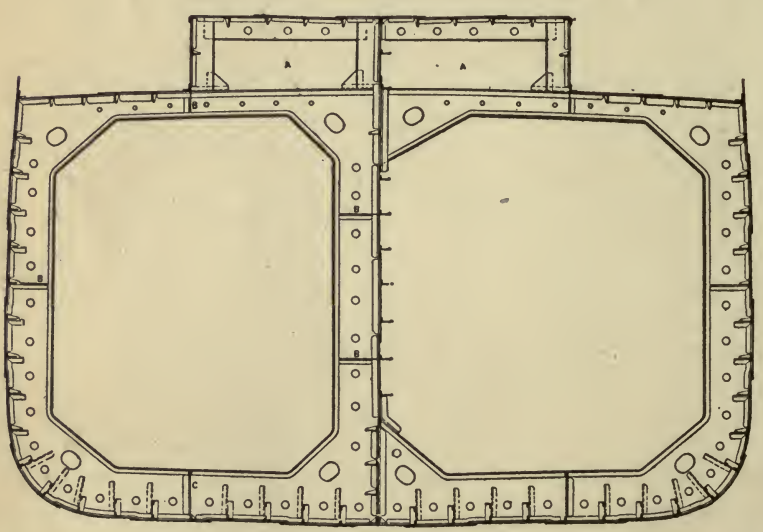

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FIG. 45.— TANK VESSEL

process is suitable for cargoes such as mutton, which is commonly shipped in frozen whole carcasses which remain frozen stiff throughout the voyage. The temperature of the hold is kept at 15 degrees Fahrenheit without injury to the meat. Beef, on the other hand, is greatly injured by freezing and is shipped in a chilled state, the temperature of the hold being maintained just above freezing point. Great care is required to keep the temperature within one degree of the required point, and many refinements are introduced into the refrigerating apparatus with this object in view. The freezing process is also unsuitable for other commodities such as butter, milk, vegetables, and fruit.

The requirements for refrigeration are briefly an insulated hold and a refrigerating machine. Charcoal, silicate, pumice, and

granulated cork are used for insulation. The refrigerating machine is usually located between-decks or in a deck house near the insulated holds, but it may be placed in the main engine room.

Various systems of refrigeration are employed, principally the following:

(1) Cold-Air or Dry-Air System.— Air drawn from the hold is compressed, which makes it hot, and the heat is abstracted by passing the air through a coil surrounded by sea water and a coil surrounded by cold air. When again allowed to expand it becomes intensely cold and is then returned to the hold through trunkways. The passage through the coil surrounded by cold air causes the loss of its moisture, hence the name "dry air."

(2) Carbonic-Anhydric System.— Carbonic acid gas is compressed instead of air and through compressing and cooling becomes a liquid. This is passed into a coil placed in a tank of brine (chloride of calcium). Here it is allowed to expand, resumes its gaseous form, and is chilled to 10 degrees Fahrenheit. The surrounding brine also becomes chilled and is withdrawn at zero Fahrenheit and circulated through long coils in the holds.

(3) Ammonia System.— This is practically the same except that ammonia gas is used instead of carbonic acid gas.

(4) Direct-Expansion Battery System.— It is sometimes found advisable to bring the air from the hold to a special chamber to be cooled and then return it to the holds at the proper temperature.

The dry-air system is suitable only for frozen cargoes where the precise degree of cold is unimportant, while the carbonic-acid and ammonia-gas systems have both advantages and disadvantages. The former is difficult to operate in tropical climates because sea water used for cooling is sometimes too warm and great pressure is required to liquefy at a high temperature. But volume for volume carbonic acid gas is heavier than ammonia and is consequently a more efficient refrigerating medium. Therefore, the ammonia compressor must be large with consequent loss of space. Ammonia cannot be used in the main engine room because the slightest leakage fills the room with noxious gases. Carbonic acid gas, while dangerous in quantities, is respirable in small quantities without inconvenience, but is odorless and leaks are difficult to detect.

Insulation is of some disadvantage in a vessel which must also

be used in other trades. The insulation space is lost for other cargoes, screws cannot be used for compressing cargoes of wool and heavy dead-weight cargo cannot be carried without danger of damaging the insulation. Refrigeration has, nevertheless, become an important factor in modern life, which is seen from the fact that immense frozen and chilled meat trades have grown up in New Zealand and the Argentine. The Shaw, Savill & Albion Company, operating between London and New Zealand, is said to transport over 2,800,000 carcasses per annum and in England 20 pounds of imported meat per head is consumed a year. Some of these refrigerating vessels reach a length of 470 feet with a capacity of 100,000 carcasses of 10,000 tons dead weight. The following is an illustration of a typical refrigerator ship.

(q) *Steam Schooner.*— A type of vessel almost peculiar to the Pacific Coast deserves to be included in this list. The steam schooner is a development of the sailing schooner and, like its predecessor, is mainly used in the lumber trade. They are heavily built vessels, having the motive power and superstructure well at the stern, and were described by Mr. Frank W. Hibbs, in a paper before the Society of Naval Architects and Marine Engineers, as follows:

> These vessels are built similarly to the sailing schooner, with greater proportionate beam than the ordinary steamer, with high freeboard, great sheer forward, a topgallant forecastle, and raised quarter-deck. They have low power and are built to very heavy scantlings, and are the staunchest vessels that are seen on the coast. They carry large deck cargoes of lumber, and are regarded as the most profitable type of coasting cargo vessels.

Their general structure resembles that of a sailing vessel but their motive power is exclusively steam. Between the forecastle and the bridge located far aft there is an immense unobstructed deck space available for lumber. On page 95 is shown a plan of a vessel of 1600 tons capable of transporting 1,500,000 feet of lumber.

2. Awning-Deck Vessel.— Thus far we have been considering only vessels in which the full strength of scantlings is maintained through the depth. But where maximum dead-weight capacity is not the primary consideration this is unnecessary, and the construction is accordingly modified as in the awning- and spar-deck ships. The former is a three-deck vessel with a lower main deck

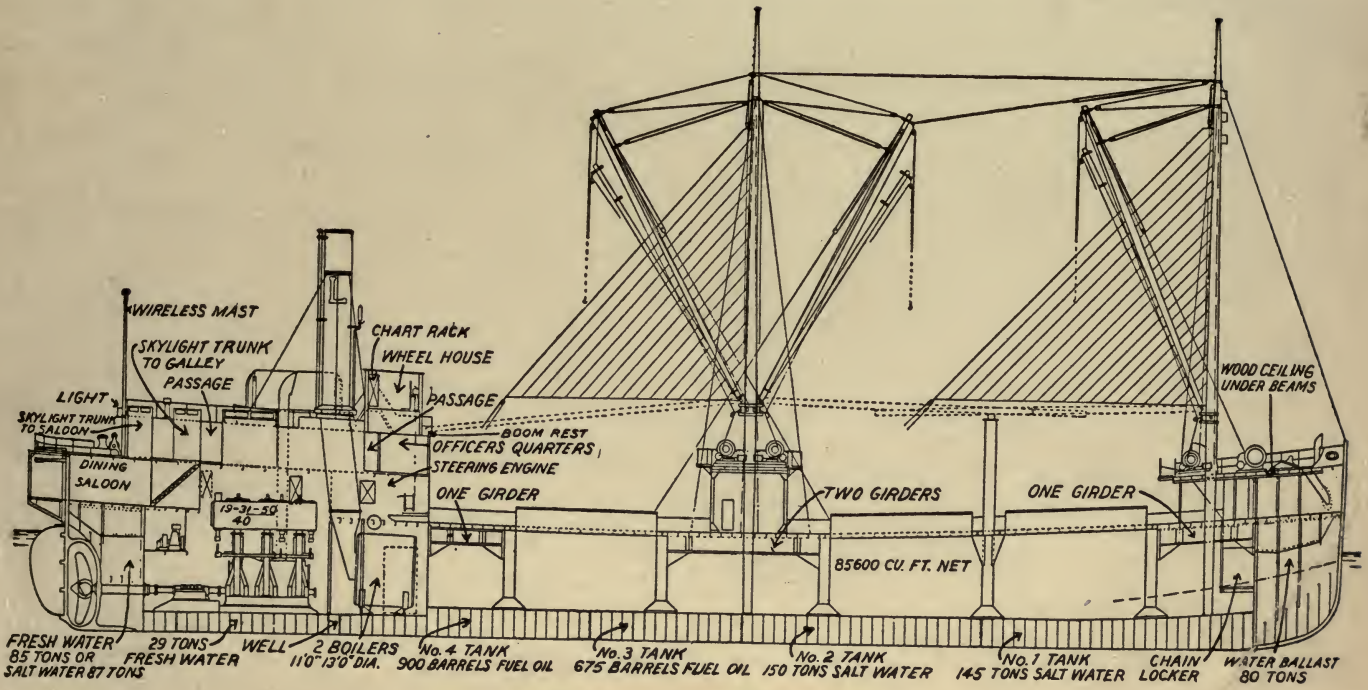

FIG. 46.— STEAM SCHOONER

and awning deck. It is the lightest type of overseas boat, and the full structural strength is maintained only up to the main deck, the awning deck being of very light construction. As originally understood, it was merely a light continuous superstructure from stem to stern on the main deck, but early awning decks were too light and vessels later tended to approach a class intermediate between the original awning-deck type and a full-scantling vessel. This has caused confusion between the awning-deck vessel and the spar-deck vessel, a heavier type described later. In a complete superstructure vessel of awning-deck type, the freeboard is measured from the second deck, but by reason of the awning deck the freeboard is very much less than for a flush-deck vessel of the same dimensions as the hull proper of the awning-deck vessel. It must be emphasized that the awning deck is an integral part of the hull, and not a superstructure, such as a forecastle, poop, or shelter deck. It might be crudely described as a combination of the lower part of the hull of a full-scantling two-deck vessel combined with the upper hull of a very lightly constructed ship. The difference in freeboard obtained by the awning deck is relatively much greater for small vessels than for large vessels. A flush-deck vessel of 8-feet depth with a freeboard of 12 inches would have as an awning-deck vessel a freeboard of only 1 inch, a reduction of 91 per cent. On the other hand, a flush-deck vessel with a depth of 50 feet and a freeboard of 10 feet 2 inches, has a reduction of 23 per cent. This is reasonable because the depth of the small vessel is doubled by the awning, while that of the larger is increased only 16 per cent. With increased strength above the standard allowance in freeboard is made. An illustration of the midship section of an awning-deck vessel would be useless in this connection because the scale would be too small to show the relative size of scantlings above and below the main deck.

As distinguished from the heavy cargoes for which the full-scantling vessel is particularly suitable, we have many bulky cargoes of small density, as, for example, cotton and many forms of package freight. With this type of cargo all the available space of a full-scantling vessel could be occupied and the vessel not immersed to its maximum draft. What is wanted, therefore, is a vessel with considerable volume, less strength, and consequently smaller immersion, displacement, and carrying power. In other

words, a smaller proportion of the enclosed volume is used for displacement at the load draft. It would be impossible to bring the full-scantling vessel down to the load line, the excessive strength would be unnecessary and costly, and the awning-deck vessel has a larger freeboard and drier decks. It is, therefore, available for the carriage of heavy cargo in the lower holds with passengers or package freight between decks. The original very light type is now used for purely passenger steamers.

(a) *Partial Awning-Deck Vessel.*— Sometimes the awning deck does not extend the full length of the vessel. Such vessels may be built either with or without a poop as illustrated below, and

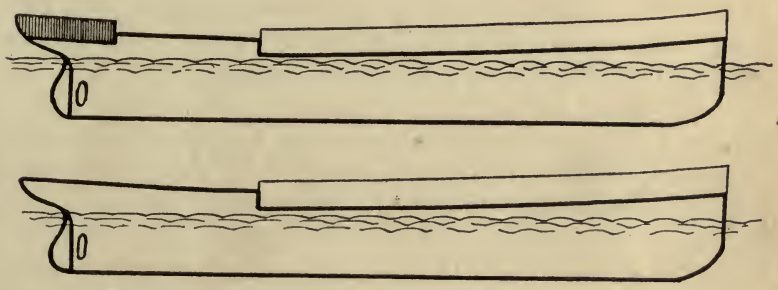

FIG. 47.— AWNING-DECK VESSEL

the partial awning deck is useful for the carriage of light cargo, cattle, or passengers, reserve buoyancy, and protection to the engines. Where the partial awning deck is brought in harmony structurally with the strength of the raised quarterdeck less freeboard is required than for standard awning-deck vessels.

3. **Spar-Deck Vessel.**— This is a three-deck vessel with a lower, main and spar deck, the upper portion of the hull supporting the spar deck being of lighter construction but more substantial than in the awning-deck type. The uppermost or spar deck is considered as the strength deck, as in the three-deck vessel, and for the same reason. Up to the main deck, the vessel is practically similar to a two-deck vessel except that the spar deck constitutes so valuable an erection or rather integral part of the hull that allowances are made in calculating length to depth. Thus a vessel of 16 depths to its length is considered as 15 which results in a great saving in freeboard, which is measured downward from the spar deck. Frequently these vessels are built in

excess of requirements and by carrying the reverse frames up to the spar deck and adding material, the vessel might be brought up to the three-deck standard with consequent lessening of freeboard. The standard height of the spar deck between decks is 7 feet.

This vessel is of a type intermediate between a full-scantling and awning-deck vessel and is available for mixed cargoes and these of moderate density. The between-deck space under the spar-deck was originally intended only for passengers but later was strengthened for freight. This type of vessel has been very popular in recent years.

Unrigged Craft.— We may briefly consider several types of craft. These include, barges, tank barges, scows, lighters, dredges, rafts, etc. Of these the most important is the barge, a name applied to vessels of many styles. Frequently the barge is merely an old steam or sailing vessel whose usefulness for the original purpose has disappeared; on the other hand, it may be a specially constructed steel vessel adapted for a particular purpose. These vessels have fulfilled two needs: they have displaced steam and sailing vessels to some degree in the carriage of very heavy bulk commodities, and have supplemented the work of these vessels by relieving them of products for which the barge is more suitable. More than one-half the United States' tonnage of this character is used on the Atlantic Coast and more than one-quarter on the Mississippi River, where the principal commodities carried in this type of vessel are coal, iron ore, pig iron, lumber, shingles, railroad ties, sand, stone, gravel, brick, cement, lime, and similar heavy commodities. The number and tonnage of tugs and unrigged vessels constitute practically one-half of the total for the Atlantic and Gulf Coasts and 95 per cent of the tonnage of the Mississippi River. The following tables will give an idea of the importance of such vessels in the United States according to the census compiled in 1916 and published in 1919.

The total tonnage of all vessels in the United States was estimated by this census to be 12,249,990, and the tonnage of the unrigged vessels amounts to 4,981,254 or over one-third of this total. A considerable decrease is noted in the tonnage of unrigged vessels between the years 1906 and 1916, but this is largely accounted for by the decline in the canal boats on the Erie Canal

TABLE 1

NUMBER, GROSS TONNAGE, AND VALUE OF UNRIGGED VESSELS IN THE UNITED STATES

	1916	1906	1889
Number of vessels	20,311	20,263	16,937
Gross tonnage	4,981,254	7,129,631	4,973,356
Value	97,219,760	64,994,249	22,231,953

TABLE 2

UNRIGGED VESSELS IN THE UNITED STATES BY GEOGRAPHICAL DIVISIONS, 1916

	Number	Gross tonnage	Value
Atlantic and Gulf Coasts	10,772	2,876,238	$68,732,989
Pacific Coast and Alaska	1,673	253,561	8,063,288
Great Lakes and St. Lawrence	857	181,611	8,157,884
Mississippi River and tributaries	5,539	1,501,532	9,887,449
Canals and other inland waters	1,470	168,312	2,378,150
Total	20,311	4,981,254	97,219,760
All vessels in United States	37,894	12,249,990	959,925,364

and the decrease on the Mississippi River in the number of coal barges in the big Pittsburgh fleets. Table 2 shows the Atlantic Coast and Mississippi River as the leading sections of the country in this type of craft. The figures indicate that its tonnage has increased about 27 per cent on the Atlantic Coast from 1906 to 1916, and about 64 per cent on the Pacific Coast during the same period. A considerable portion of the Pacific Coast increase is accounted for by Alaska and the construction of barges for the petroleum trade. On the Great Lakes, Mississippi River, and other inland waters, there were decreases of 14 per cent, 64 per cent, and 29 per cent, respectively. These figures do not include schooner barges, which were placed in the sailing-vessel class by the census authorities.

One may distinguish the small barges from the larger and heavier types used for seagoing purposes. The latter consist principally of "schooner barges," a name applied because they are fitted with a limited amount of canvas. In fact, the sails are little used for propulsion except in case of necessity to avoid

absolute helplessness when cut loose from the towing vessel. These are built to carry over 3000 tons at times and may be towed singly or in fleets of two or three. The towing is either by tug, by a towing steamer adapted to the purpose or by a loaded steamer. The latter method is comparatively little used, being uneconomical as compared with the two former methods. The main source of building material for these vessels continues to be wood, although steel barges are also being constructed.

The advantages of towing unrigged craft are principally the following:

1. The lower initial cost of construction of the vessel and in some cases the utilization of otherwise valueless hulls. At one time it was even the practice to build barges for one or two trips on the Mississippi River, selling them as lumber or using them for other purposes upon reaching destination.

2. The complete utilization of propulsive machinery, the towing vessel being able to go on with its work while the barges are being loaded or unloaded.

3. A reduction in the crew otherwise necessary, only three men being required for a large seagoing barge.

4. Greater regularity of service than is possible with sailing vessels, which previously furnished the cheap transportation.

5. Ease and speed in loading and unloading.

6. Low cost of repairs.

The disadvantages of this method of transportation are:

1. Interference with work by rough weather. Until recent years the loss of life and cargo on these vessels was disproportionately large due to their helplessness in bad weather, overloading and the lack of adequate life-saving facilities.

2. As a result of the above conditions the marine insurance premiums are high and many barges and even tugs sail uninsured.

3. Their limitations as far as kind of cargo is concerned.

Special tank barges are provided for the transportation of petroleum, by fitting barges with tanks in a manner similar to steamers. Some of these vessels have a capacity of 2,500,000 gallons of oil. Seventeen such vessels, built of metal and aggregating about 20,000 gross tons, were added to the Pacific Coast fleet between 1906 and 1916. These vessels are completely equipped with engines for pumping, etc., and automatic towing gear operated by hydraulic machinery.

A considerable amount of lumber is moved in the form of rafts by merely tying together the cargo and floating it downstream or towing it, especially in the Mississippi valley and on the Pacific Coast. Such rafts have also been used for open sea navigation in favorable weather.

Other types of unrigged vessels, such as scows, lighters, floating docks, floating lighthouses and similar harbor craft belong more properly to a volume on harbor management.[3]

Modern Developments.— In closing it might be stated that the principal developments in cargo vessels of recent years have been the following:

1. In order to obtain the maximum cargo the lines of the vessels have been filled out, increasing the block coefficient, until the extreme is reached in Great Lakes steamers with a figure of 88 per cent.

2. Portions of the vessel above water which make no useful contribution to cargo-carrying capacity but would be measured are cut down to the minimum requisite for buoyancy and stability.

3. To provide for return journeys empty or partially loaded, large water-ballast spaces have been provided abreast of and above the cargo spaces.

4. Holds have been cleared of obstructions so that stowage space is unbroken.

5. Hatches have been increased in size and number.

REFERENCES

1. Huebner, G. G.: *Ocean Steamship Traffic Management.* D. Appleton & Co., New York, 1920. Chap. V. (The business organization of the line and the tramp steamer and the methods of operation; charter parties; ship brokers.)
2. Smith, J. R.: *Organization of Ocean Commerce.* Publications of University of Pennsylvania, Philadelphia, 1905. Chaps. II and III. (Relative advantages and economies of line and tramp operation.)
3. Sparks, T. A.: "Relation of the Contractor or Speculator to the World's Ocean Transportation Problem." *Annals of American Academy of Political and Social Science,* September, 1914, pp. 232–236. (An explanation of the necessity of the speculator in ocean space, particularly in the tramp business.)

[3] See MacElwee and Taylor, *Wharf Management, Stevedoring, and Storage,* D. Appleton & Co., New York, 1921.

4. JOHNSON, E. R., and HUEBNER, G. G.: *Principles of Ocean Transportation.* D. Appleton & Co., New York, 1918. Chaps. XXI and XXII. (On the factors governing ocean freight rates and passenger fares.)
5. HUEBNER, S. S.: "Steamship Line Agreements and Affiliations." *Annals of American Academy of Political and Social Science,* September, 1914, pp. 75–111. (On the universal prevalence of agreements and associations and the various methods employed to enforce agreements and prevent competition.)
6. HOLMS, A. C.: *Practical Shipbuilding.* Longmans, Green & Co., London, 1916. Vol. I, Chap. VII. (On freeboard and the load line.)
7. HOLMS, A. C.: *Practical Shipbuilding.* Longmans, Green & Co., London, 1916. Vol. II. (Plans and diagrams of types of vessels and their parts.)
8. WALTON, THOMAS: *Steel Ships.* Griffin & Co., Ltd., London, 1918. Chap. VI. (On types of vessels according to construction characteristics, with illustrations and diagrams.)
9. MONTGOMERIE, J.: "Arrangement and Construction of Oil Vessels." *Cassier's Magazine,* 1911, Vol. 40, pp. 737–752.

CHAPTER VI

TYPES OF MARINE ENGINES

The present chapter initiates a discussion of the various types of vessels according to motive power by describing the evolution of steam as a means of propulsion and the kinds of marine engines now in use. The succeeding chapter will deal with oil-burning and internal-combustion engines. Improvements in steam navigation are appropriately divided into two parts: (1) the problem and period of effective steam generation, in which the goal is the production of the maximum energy from a given quantity of fuel; and (2) the problem and period of steam utilization, in which the object is economically to apply the energy produced so as to achieve the maximum results. The maximum result desired, of course, may be either extremely high speed or the carriage of a large tonnage at a reasonable cost.

It is profitless to consider the controversy as to the first successful application of steam to marine propulsion; many individuals contributed to the development of a satisfactory engine. For a considerable time, as has been previously described, the sailing vessel and the steam vessel were in competition, and for some time the enormous coal consumption of the steam engine made its use impossible save on the shortest voyages. So uncommon was the steamer that one was chased by a revenue cruiser for a day in the belief that it was a ship on fire. The earliest type of engine of any prominence was the *beam engine,* familiar to-day in the ferryboat. This was suitable for river and lake navigation but impossible for ocean travel because (1) it made the vessel top-heavy and (2) the beam protruded through the deck which for ocean service had to be covered in.

It was, however, easy to adapt the beam engine by converting it into the *side-lever engine.* This is accomplished by placing the beam below instead of above the cylinder and as far down in the ship as possible. The illustration on page 105 shows the application of this type of engine to a paddle-wheel steamer. For many

A Classification of Marine Engines

I. Utilization of steam pressures
   - A. Simple, utilizing steam at one pressure
   - B. Compound { Double expansion / Triple expansion / Quadruple expansion } utilizing steam at both high and low pressures

II. Action of steam
   - A. Single-acting, the steam acting on one side of piston and the return of the piston not being a working stroke
   - B. Double-acting, the steam acting alternately on both sides of the piston and both strokes being working strokes

III. Transmission of power
   - A. Direct-acting, the crank-pin of the revolving shaft being directly connected with the piston
   - B. Indirect-acting, a lever being interposed between the piston and the connecting rod. Either with or without a beam

IV. Construction of cylinder
   - A. Oscillating cylinder, the cylinder moving to accommodate itself to the action of other parts of the machinery
   - B. Stationary cylinder, in various positions, such as
     1. Horizontal
     2. Vertical..... { Upright / Inverted }
     3. Inclined

V. Use of exhaust steam
   - A. Noncondensing
   - B. Condensing..... { Surface condensation / Injection condensation }

VI. Manner of applying steam
   - A. Reciprocating engine, where the steam works on a piston
   - B. Turbine engine, where the steam works on movable revolving blades
     1. Impulse-and-reaction turbine
     2. Impulse turbine

years, in fact until the introduction of the screw propeller about 1860, this was the recognized type of marine engine. The *Sirius, Great Western, Britannia, Hibernia, America, Arabia* and *Persia,* all prominent early transatlantic steamers, were equipped with it, Its working parts were well balanced, it was strong and could easily be used for auxiliary work, such as air pumps, but it was heavy, increasingly expensive as it became more complicated, con-

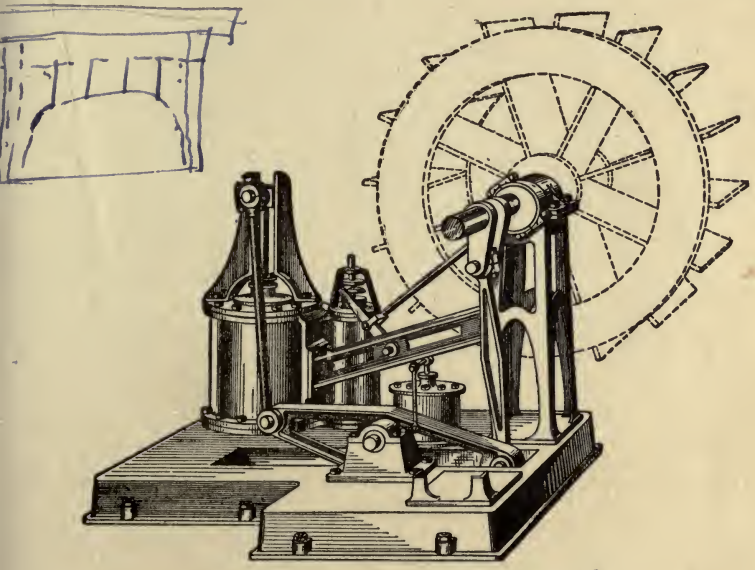

FIG. 48.—SIDE-LEVER ENGINE - S.

sumed entirely too much space and a tremendous quantity of coal. The *Sirius,* crossing the Atlantic under steam power for the first time, exhausted the coal supply and burned her spars in order to reach port. These engines were supplied with cylinders from 60 to 72 inches in diameter, boilers with pressures of from 10 to 12 pounds per square inch and from 400 to 750 horse power. The speed attained was from 7 to 9 knots per hour. By 1862 this type of engine had been developed to 4000 horse power with a speed of 13 knots per hour, having cylinders 8 feet 4½ inches in diameter and a boiler pressure of 25 pounds per square inch. No more than two cylinders were ever used.

During the period of transition from the paddle steamer to the screw propeller the *oscillating engine* was introduced. The beam

or lever was eliminated by connecting the piston of the cylinder directly with the crank shaft. This required that the cylinders sway or oscillate from side to side, being placed on trunnions in the same manner as a cannon. The condenser was placed between the two cylinders. The illustration below shows clearly the principle and is interesting also as showing the earliest of such engines. The oscillating engine, in order to be applied to the screw propeller, had to be supplemented by gearing in order

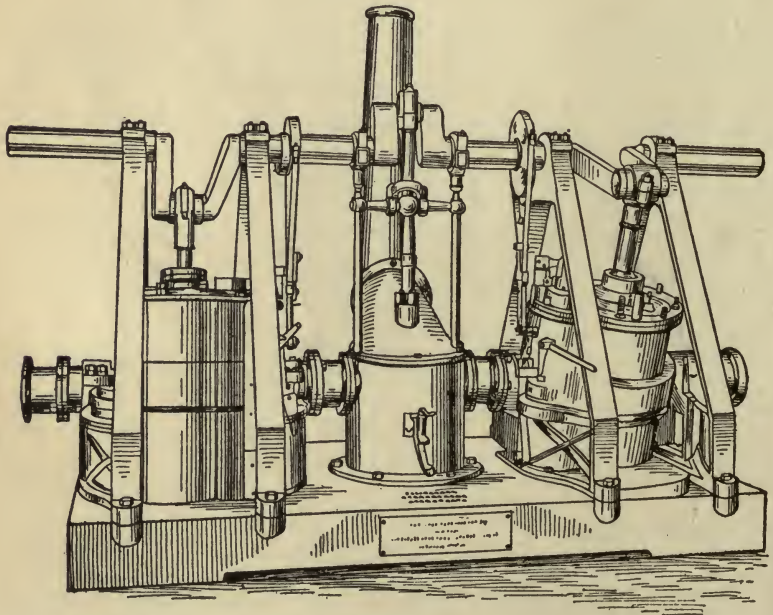

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FIG. 49.— OSCILLATING ENGINE

to give the propeller shaft the requisite speed — three to six times as much as was necessary for paddle wheels.

This type of engine had the advantage of saving considerable space, and was light in weight. It was employed in the *Great Eastern,* a transatlantic vessel nearly twice the size of any vessel previously built; the *China,* a screw steamer of 1862; and the *Candia,* a Peninsular and Oriental Company vessel. From two to four cylinders were used, with diameters of from 70 to 80 inches, from 2500 to 5000 horse power, and a boiler pressure of

from 22 to 30 pounds per square inch. The coal consumption of the *Great Eastern* was 350 tons per day, greater than some of the large liners of the twentieth century. The exhausted steam was condensed in a separate cylinder by a jet of cold water, a system which cannot be used with a boiler pressure of over 35 pounds.

Thus far, the developments have mainly been to utilize, as far as possible, the energy produced by the more or less unsatisfactory engines. For paddle-wheel steamers direct-acting engines were

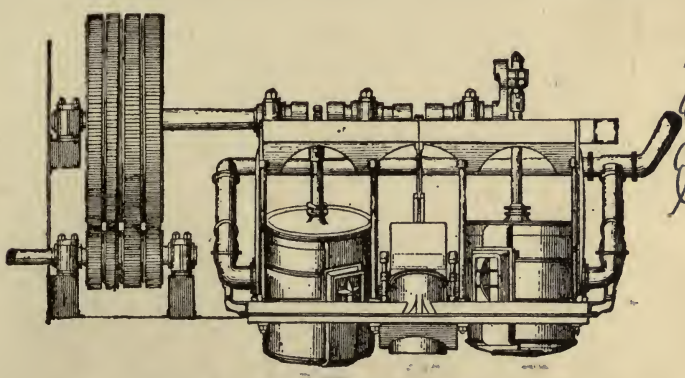

FIG. 50.— OSCILLATING GEARED ENGINE

employed. For the screw propeller these were unsatisfactory because with low-pressure boilers the speed of the piston was insufficient to give the required revolutions to the propeller shaft. Gearing was therefore introduced to attain this result. Strangely enough the next development was away from gearing and back to the direct-action engine. This was made possible by the introduction of the double-expansion or compound engine.

The *compound engine* allows the steam to enter one cylinder at high pressure and, after having moved the piston in this cylinder, to escape into one or more other larger cylinders where the pistons are moved by direct expansion. Triple-expansion was in use shortly before 1890 and quadruple-expansion was introduced about 1900. Considerably more work is thus performed by the same steam at much lower cost. The pressure was increased from 30 to between 60 and 100 pounds per square inch by the compound engine, and from 125 to 160 pounds by the triple-expansion engine, and from 210 to 220 pounds by the quadruple-expansion engine. Also, the coal consumption was reduced by

the compound engine to one-half what it had been in the most economical previous engine. From a coal consumption of 4.7 pounds per horse power per hour in 1840 there was a decline to 3.75 pounds in 1852 by improvement of boilers; to 2.5 pounds in 1873 by the compound engine; to 1.5 in 1892 through the triple expansion. The multiple-expansion principle, therefore, contributed to the development of marine propulsion both through the improvement in the creation of energy and through the utilization of such energy by making possible the direct-action engine.

Along with greater steam pressure went a change in methods of condensation. The jet condenser was unsatisfactory because

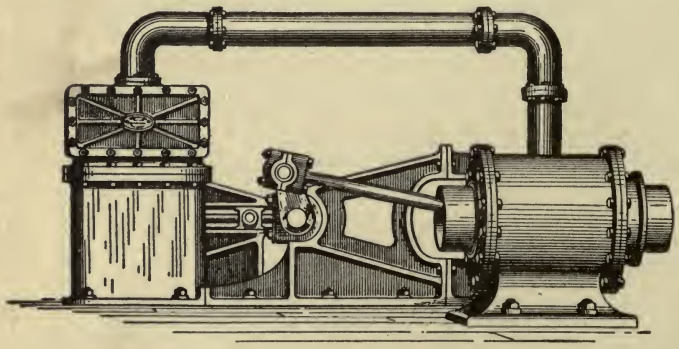

FIG. 51.— TRUNK ENGINE

salt water was introduced into the boilers and the intense heat caused a coating of sulphate of lime. A surface condenser is now used, consisting of a number of brass tubes through which a stream of cold water circulates. These pipes are thereby kept cool and condense the exhaust steam fed to them by the cylinders. The condensed steam may then be drawn off by a feed pump and again supplied to the boiler.

The direct-action engines made possible by the two preceding improvements were of various types. In the *trunk engine* the cylinder is placed horizontally at right angles to the propeller shaft. The trunk passes through a steam-tight stuffing box in the cylinder cover and is wide enough to allow for the oscillations of the connecting rod. The illustration above gives an idea of this type of engine, which became unsatisfactory as steam pressure increased, because of the increased friction of the stuffing boxes. The cylinders of the trunk engine were also sometimes placed

upright with the piston acting upward, sometimes inverted diagonally, and sometimes the horizontal and inverted arrangements were combined.

The engine which has thus far been the most important in modern steam navigation, dating from about 1870, was the inverted, direct-action reciprocating engine. The cylinders are inverted above the propeller shaft and the connecting rods from the pistons are directly attached to the cranks of the shaft. As stated previously, the efficiency of the reciprocating engine was greatly increased by the introduction of the compound engine, utilizing steam at high and low pressure. The triple-expansion engine still further elaborated this idea into three stages of utilization — high, medium, and low pressure — and the three-crank design of this engine has retained its popularity until the present time. It enabled the development of a higher initial steam pressure of from 175 to 200 pounds, and a more complete utilization of energy. By extending the principle, the quadruple-expansion engine was developed which increased the steam pressure about 8 per cent. While the triple-expansion type is still useful in cargo

	Wilhelm der Grosse	*Kensington*	*Deutschland*
	Triple	Quadruple expansion	Quadruple expansion
Purpose	Mail steamer	Pass. and cargo steamer	Fast steamer
Owner	North German Lloyd	International Navigation Company	Hamburg-American Line
Number of engines	2	2	2
Total indicated horse power	28,000	8,300	34,000
Number of revolutions	78	86½	78
Boiler pressure	178	200	214
Number of cylinders	3	4	6
Diameter of cylinders			
High pressure	4′ 4¼″	2′ 1½″	3′ 6⁹⁄₁₀″
			3′ 6⁹⁄₁₀″
Medium pressure	7′ 5¾″	3′ 1½″	6′ 1⁶⁄₁₀″
		4′ 4½″	8′ 7⁹⁄₁₀″
Low pressure	8′ ½″	6′ 2″	8′ 10³⁄₁₀″
			8′ 10³⁄₁₀″
Stroke	5′ 8⅞″	4′ 6″	6′ 8⁄₁₀″
Speed of ship	22 knots	16 knots	23 knots

carriers on shorter voyages, the quadruple engine has superseded it for large vessels and passenger ships, particularly on long voyages. Its advantages are (1) ability to take advantage of higher steam pressure; (2) superior smoothness; (3) development of greater speed.

Its disadvantages as compared with the triple-expansion engine are increased weight, cost and upkeep. The added first cost and more difficult supervision are factors of particular importance in cargo vessels. In all types of reciprocating engines, however, at least three limitations to increasing efficiency were encountered. Improvements in steam consumption were becoming difficult, the size of the power units was becoming tremendous, and any reduction in weight involved an increase in the speed of rotation with its attendant difficulties. Thus the conditions were favorable to an entirely new method of steam application.

Turbine Engines

It would hardly be correct to speak of the deficiencies of the reciprocating piston-type engine in view of the great advancement in navigation made possible by its use. Nevertheless, it was inevitable that improvements should be desired and accomplished, and of these the most important was the application of the turbine principle. This is not unlike the water turbine in essence, the power being generated by the impact of steam upon movable blades. Turbine engines of marine efficiency may be divided into two main classes, depending upon the manner in which the steam is applied to the movable blades, namely (1) the impulse-and-reaction type, and (2) the impulse type. In both the impulse-and-reaction type and the impulse type two problems must be solved: (1) The steam, when issuing under pressure, must take a single direction and not disperse; (2) the velocity of the moving parts of the mechanism must be great enough efficiently to utilize the velocity of the steam. To take full advantage of a jet of steam in a turbine with a single wheel would give the moving parts a peripheral velocity of 2000 feet per second which would be very difficult to gear down to a workable speed and would require materials not now available to withstand the resulting stress on the moving parts. These problems are best illustrated by comparing two of the principal engines now in use.

Impulse Type.— The principle involved is to apply a jet of steam to movable blades in such a manner that the impact will cause the movable blades and the drum to which they are attached to revolve. The pressure energy is thereby converted into velocity energy, and the velocity attained from steam is far greater than that developed with water because of the lesser density of steam. The steam streams from one end to the other through the ringlike space between a cylinder and a revolving drum contained therein. To the casing which surrounds the drum is attached a series of parallel rings of fixed guide blades projecting inward, and between these rings of guide blades and attached to the drum is a series of movable blades which revolve with the drum. The passage of the steam through the spaces thus arranged causes the movable blades and the drum to which they are attached to revolve. The result is in effect an operation the reverse of an electric fan. In the fan the revolution of the blades creates a current of air while in the turbine a current of steam causes a revolution of the blades.

Impulse-and-Reaction Type.— This is exemplified by the Parsons turbine. Its efficiency was demonstrated by an experimental vessel of 100 tons called the *Turbinia* in 1897. The De Laval turbine with one wheel of moving blades was inadequate for work on a large scale. Parsons divided the expansion of the steam, which produces the velocity, into a series of steps or stages, enabling full utilization of the energy of the steam without making the velocity of the moving blades too great. The range of pressure through which the steam passes in any one stage is not great enough unduly to increase the velocity. At each step in the expansion the steam streams through a ring of fixed guide blades and is thrown upon a ring of movable blades. At each step there is a reaction as well as impulse effect. The steam loses pressure as it passes each ring of moving blades and each pair of fixed and moving blade rings virtually constitutes a separate turbine. There may be from 100 to 200 stages in large marine turbines. As the steam progresses and loses pressure its energy is fully utilized down to the lowest point attainable. Marine turbines are divided into high and low pressure parts, usually three in number and each driving a separate propeller shaft. In many turbines the rotary speed developed is very high and where too great to be directly imparted to the propeller shaft a system of gearing is

introduced to reduce the revolutions to, say, one-tenth on the main shaft.

In the Curtis turbine no drop in pressure occurs while the steam is passing through the rings and the only change in velocity is due to friction, thereby eliminating the reaction element. While the Parsons turbine utilizes the energy of the steam without unduly increasing the speed of revolution by dividing the heat drop

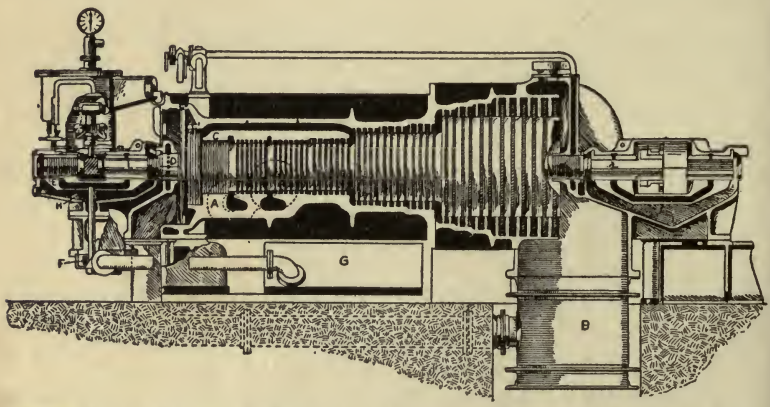

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FIG. 52.— PARSONS TURBINE

into stages, the Curtis accomplishes this result by allowing the energy to expend itself upon a series of rings or blades, usually three in number. The steam is guided from one set of blades to another, in the sense that the steam acquires new velocity at each set of rings and gives this up to the moving blades of that step, passing to a second set of nozzles in which it undergoes a second drop in pressure and acquiring velocity which it imparts to a second set of movable blades. Thus, the Curtis may be regarded as two turbines with their shafts connected and the Parsons as a single turbine in which many changes in pressure occur in the passage of the steam from one blade to another.

The turbine at first proved especially adaptable to large and fast vessels, though later applied to slower speeds. The considerations leading to its adoption for passenger liners and faster cargo vessels were the following:

1. The adaptability of the turbine to greater power develop-

ment in a single unit. As has been shown, the triple-expansion developed into quadruple-expansion only at the expense of increased weight, complexity, and coal consumption, while the increased efficiency was relatively small. Increased size and speed were desired, and the turbine made these possible. The *Adriatic,* built in 1906, was 709 feet long with quadruple engines of 15,000 horse power, speed 15 knots; the *Deutschland,* built in 1900, was 663 feet long with quadruple engines of 34,000 horse power and a speed of 23 knots; the *Lusitania,* built 1907, was 785 feet long, equipped with Parsons turbines of 68,000 horse power and with a speed of 25 knots.

This concentration of power would probably have been impossible save for the turbine.

2. Less weight of machinery and coal. One writer has compared the machinery weight of a four-screw, triple series turbine with water-tube boilers of 1913 with a twin-screw triple-expansion engine, cylindrical boilers, of 1893, both Atlantic passenger vessels, and finds the former is but 60 per cent of the latter in weight. A similar comparison for cargo vessels showed the 1913 engine weighed but 84 per cent of the 1893 engine.

3. Decreased cost of operation. The comparison of the above mentioned vessels as regards relative fuel consumption showed that in the Atlantic passenger vessels the 1913 vessel's consumption was 94 per cent of that in 1893, and the 1913 cargo boat used 76 per cent of the fuel consumed by a similar vessel in 1893.

4. Vibration due to machinery reduced.

5. Construction and operation simplicity attained, reducing delays and cost incident to repairs.

6. Lower center of gravity of machinery, resulting in increased headroom above the machinery, greater stability and more deeply immersed propellers which are not so often " racing " out of water.

7. Economy of space.

8. Reduction of friction due to absence of sliding parts.

As a result of the above advantages the total horse power of steam turbines applied to marine propulsion increased from practically zero in 1899, to 25,000 in 1900; 35,000 in 1902; 75,000 in 1903; and 390,000 in 1906.

The latest principal developments in engines have been connected with overcoming some of the defects of the turbine, the most vital of which were:

1. The difficulty in reversing.
2. The reduction of the high speed of the rotating parts to a speed which will accommodate itself to the efficient velocity of the propellers.

The original turbine could not be run astern and either a second turbine or some kind of transformer was necessary. The blades of the second turbine are placed in the opposite way, so that when the ship is going ahead they revolve idly. The turbine's efficiency was early shown at high speeds and this continued to be its strong point. It was impossible to impart the full velocity of the revolving turbine shaft to the propeller shaft of a vessel not designed to make high speed; the water, instead of being used for propulsion, was simply churned up without result. Some form of reduction was therefore necessary. One method was to have the turbine drive an electric dynamo, the current of which would operate the propeller shafts at the speed desired. This also solved the problem of reverse speed.

The advantages of the electric system, briefly stated, are:

1. Economy in the consumption of steam.
2. High efficiency at low speeds.
3. Reversibility without a special backing engine and reverse power nearly 100 per cent of forward.
4. A saving in weight and space.
5. Transmission adaptable to any power.
6. The turbine is uninfluenced by the racing of the screws.

Its disadvantages are:

1. The complexity of the necessary accessories.
2. The possible effect of electricity on the ship's instrument, which has not yet been demonstrated.
3. Difficulty in ventilating generators and cooling resistances, which is denied.

Another method is to install a gear wheel transmission, the speed of the turbine shaft being reduced by a series of gear wheels to a speed appropriate to the propeller shaft. The loss of power is small, and while the noise is augmented the vibration through the structure of the ship is only inappreciably increased. Its advantages summarized are:

1. A reduction in weight of 15 per cent over the directly connected turbine.
2. Simplicity of mechanism.

3. Easier repairs.
4. A possible speed reduction ratio of about 30 to 1.

Its disadvantages are:

1. Some noise, though slight.
2. Some wear.
3. Nonreversibility.
4. Possible limitation of power, which is disputed.

Hydraulic transformer gearing is also used, centrifugal pump wheels being keyed to the rotor shaft and impulse-reaction water turbine wheels similarly secured to the propeller shaft. The water flows from the pump through the water turbines and so drives the shaft ahead if sent through one set and astern if sent through the other. Its advantages are:

1. No limitation as to power.
2. No additional noise or wear.
3. Saving in weight compared with direct turbines.
4. Reversibility without separate turbines and backing power equal to about 85 per cent of forward.

Its disadvantages are:

1. An efficiency of about 89 per cent of the geared turbine.
2. A limitation in speed reduction to a ratio of about 6 to 1.
3. Complicated mechanism.

The early program of the United States Emergency Fleet Corporation called for a large number of turbine-propelled vessels. Due to the difficulty of fitting the engines to the vessels properly, however, and to the lack of experienced men to operate them, the program was later revised to encourage the production of reciprocating engines. This was generally considered to be due to deficient installation and handling rather than to inherent difficulties with the turbine, which had demonstrated its efficiency in other countries.

For the propulsion of cargo boats where the speed of the screw shafts cannot be made high enough to admit of efficient treatment in the turbine of high-pressure steam, a combination of reciprocating and turbine engines has been adopted. By using a cylinder and piston for the high pressure and a turbine for the low pressure, the turbine becomes available for slower vessels where otherwise it would have to be confined to vessels of over 15 knots. This combination was first adopted in the *Otaki*, a steamer of 464 feet length, 9900 tons dead weight. A compari-

son of this vessel with its sister ship fitted with ordinary twin-screw quadruple-expansion engines showed a difference in steam consumption per effective horse power of 20 per cent in favor of the combination engine. The latter is particularly suitable to vessels of fairly large power and moderate speed employed on long voyages. The disadvantages are increased complexity and cost and a slight increase in engine-room weight, but increased economy allows a reduction in boiler capacity and in boiler room and fuel weights, depending on the length of the voyage.

The following table[1] will show the effect of the improvements previously described by a comparison of three types of vessels in 1893 and 1913:

	Engines	Boilers	Relative Fuel Consumption	Relative Machinery Weight
1. Atlantic Passenger Ships				
1893	Reciprocating	Cylindrical	100.0	100.0
1913	Turbine	Water-tube	94.0	60.0
2. Intermediate Liners				
1893	Reciprocating	Cylindrical	100.0	100.0
1913	Combination reciprocating and turbine	Cylindrical	80.0	94.0
3. Cargo Tramps				
1893	Reciprocating	Cylindrical	100.0	100.0
1913	Turbine	Cylindrical	76.0	84.4

Marine Boilers

This subject naturally divides itself into two parts, (1) the generation of heat and (2) the transmission of heat or generation of steam. For the generation of heat, two systems of firing have been employed: the natural draft and the artificial draft, either

[1] Adapted from Alexander Gracie's *Twenty Years' Progress in Marine Construction, Institute of Civil Engineers,* cxciv, London, 1914.

induced or forced by centrifugal fans. The former is adaptable to slow freight and passenger steamers because it is simpler and economical in fuel consumption, while the latter is used on faster vessels burning over 20 pounds of coal per square foot of grate area per hour.

For the generation of steam, two types of boilers are in use, the cylindrical and water-tube. A cylindrical boiler with three internal corrugated furnaces and return tubes is now quite gen-

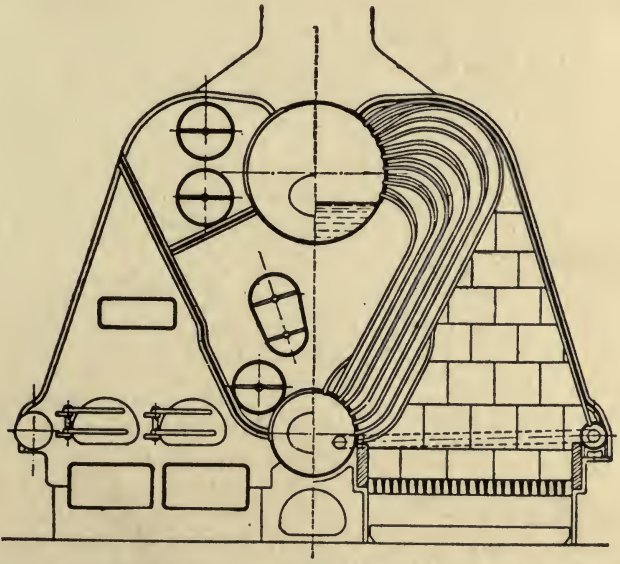

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FIG. 53.— YARROW BOILER

erally used on merchant vessels. The advantages of this boiler are its reliability and simplicity, its ability to stand hard usage, and the familiarity of engineers with it. The water-tube boiler consists of a number of tubes surrounded by heat, illustrated by the photograph above of a Yarrow boiler.

This type is much lighter than the cylindrical or Scotch boiler and can be used with a heavy forced draft. With the cylindrical boiler steam cannot be raised or reduced quickly and high pressure cannot be used in boilers of great capacity because the necessary thickness of shell makes the weight excessive. The water-tube boiler is easier to repair and as a result all parts are

likely to be properly repaired and renewed, keeping the boiler up to par while as the cylindrical boiler deteriorates the working pressure must be reduced and the efficiency sacrificed. Accidents, furthermore, are more serious with cylindrical boilers because of the large amount of water contained. But the water-tube boiler has certain disadvantages which partially counterbalance the advantages enumerated, namely:

1. More affected by irregular feeding.
2. More affected by irregular stoking.
3. Greater susceptibility to fouling.
4. Difficulty of internal cleaning.
5. Increased complication and less well-known.

Thus, cylindrical boilers maintain their popularity with all except the faster vessels. Among the more popular boilers are the Babcock and Wilcox, Yarrow, Niclausse, Schulze, Dur, Belleville, Normand, Thornycroft, White, Reid, Seabury and Almy.

REFERENCES

1. Gracie, Alexander: "Twenty Years' Progress in Marine Construction." *Institution of Civil Engineers,* London, 1914, Vol. cxciv.
2. Bauer and Robertson: *Marine Engines and Boilers.* Crosby, Lockwood & Son, London, 1905. Part I, Sect. iv; Part V, Sects. ii and iv.
3. Thomas, C. C.: *Steam Turbines.* Wiley & Sons, New York, 1910. Chaps. VII, VIII, IX, X.
4. *New International Encyclopedia.* Article on "Boilers."
5. McGinnis, A. J.: "Advance of Marine Engineering in the Early Twentieth Century." *Institute of Mechanical Engineers of United Kingdom,* London, July 29, 1909.
6. Kirkaldy, A. W.: *British Shipping.* Kegan Paul, Trench, Trubner & Co., London; Dutton & Co., New York, 1914. Chap. XIII.

CHAPTER VII

OIL-BURNING AND INTERNAL-COMBUSTION ENGINES

Importance of Oil as Fuel

The threatened exhaustion of the coal supply of the world has been referred to in so many connections that it is now generally accepted as a very real possibility. Whether its actual disappearance is an impending evil or not, recent years have exhibited an increasing tendency for the demand to exceed production, with consequent rising price. It was natural for persons interested in marine propulsion to turn their attention, therefore, to the only other great fuel available — oil. It is extremely significant that the present-day prominent fuel subject is not coal but oil, indicating a progression from an "age of coal" to an "age of oil." Rumors are circulated of possible British domination of the oil supplies of the world, international agreements respecting the Mesopotamian fields are entered into, parliamentary speeches are made indicating oil's importance as a factor in the merchant marine, and articles are written on the oil problem in the United States. Less real interest is manifested in the transfer of coal from Germany to France than in who shall control the liquid fuel supply. The automobile has been a potent factor in conditions to date; maritime requirements are likely to play an equally important part in the future. The completed program of the United States Shipping Board aggregates about 10,000,000 deadweight tons and of this, roughly speaking, one-fifth consists of coal-burning vessels and four-fifths of oil-burners. The estimated fuel oil requirements of the Shipping Board for the year 1920 are 40,000,000 barrels and for the year 1921, 60,000,000 barrels. But in this connection the statement of Admiral W. S. Benson, Chairman of the Shipping Board, is most significant.

If we are forced by conditions to return to the use of coal for our merchant marine we might as well give up the problem. Our foreign competitors are using every means so completely to control the fuel oil situation that in the very near future, if there is not some legisla-

tion that will give us the power to exert certain pressure on foreign interests, they will be able to keep us from securing the oil fuel that we must have. If you look at the map you can see where the oil is scattered throughout the world. Right in the center of the map is Persia; there is one of the biggest oil fields in the world, and we cannot get any of that. It is right in the middle of our trade routes. Take it around the Caspian Sea. We cannot get it there. Take it in India, where there are large oil wells, take it in Burma and other places. The oil that our foreign competitors control is scattered around the world. Ours is confined to our own country, with what we are getting from Mexico.

Had it not been for the interference of the war with the development of foreign marine engineering oil would now occupy an even more important position.

Two types of engines dependent upon this fuel must be sharply distinguished: the *oil-burning engine,* which except as regards fuel may be identically the same as a coal-burning engine, and the *internal-combustion engine,* which operates on a principle as distinct from the steam engine as a typewriter from a printing press.

Oil-Burning Engines

These are merely steam engines equipped with burners enabling the use of oil as fuel instead of coal; in fact, a coal-burning engine may be transformed for this purpose at very small expense and some vessels have been so modified. The advantages derived, therefore, proceed solely from the substitution of fuels.

Advantages of the Oil-Burning Engine:

1. The most obvious advantage of oil as fuel is its greater cleanliness. This is manifest not only in the loading but in the handling of the fuel after it is on board, and is especially advantageous in connection with passenger vessels. Incidentally this characteristic results in time-saving, for stores and fuel can be simultaneously taken on board without danger of contamination, and the vessel can be cleaned during the process.

2. At one time oil showed a saving in cost as compared with coal, but its price has rapidly risen within the last few years. Approximately four barrels of oil are usually allowed per ton of coal and the question of economy can, therefore, be decided almost by the application of arithmetic to current prices. In some

instances, however, it has been found that vessels whose performances were not satisfactory while burning coal developed greater efficiency and speed on oil, which introduces an indefinite factor in the equation. The possibilities of oil as fuel are enhanced in importance in the United States because of its abundance here and the possibility of American control of the product. The United States produces and consumes two-thirds of the annual petroleum output in the world. Conservation of American resources and acquisition of foreign supplies are highly important.

3. Another advantage of the oil-burner is the simplicity of control. The supply of fuel to the burner may be easily regulated to the needs of the moment with consequent economy and efficiency, while the efficient production of energy by coal depends upon proper firing.

4. Oil may be easily taken on board at small cost. Whereas a large force of men was required for coaling a good-sized vessel, oil is easily introduced by piping, resulting in a saving of both labor and time. Thus the White Star liner *Olympic,* the largest British merchant vessel afloat, is enabled by substituting oil for coal to accomplish a round trip once every three weeks, inasmuch as 5000 gallons of oil may now be taken on in eight hours. In addition, there should be pointed out the ease of transshipping oil at sea through a hose, enabling the replenishment of fuel in emergency. This is of particular potential advantage to war vessels.

5. Oil may be stowed in places unsuitable for cargo, whereas coal-bunker space reduces the carrying capacity of the vessel. Double-bottom tanks are the most common reservoir for oil fuel, and other space formerly used for fuel becomes earning space. Since bulky products form a considerable part of United States' exports this is especially important to us. It should also be noted that oil preserves the metal of the compartments where it is stored, whereas coal bunkers demand frequent scaling and painting to prevent deterioration. The additional cargo-carrying space made available by oil fuel is frequently overestimated, however, by not considering that the space otherwise occupied by coal bunkers is an inconvenient or undesirable portion of the vessel for cargo.

6. Besides the economy effected by utilizing the double-bottom tanks as fuel reservoirs and releasing other space for cargo, there is the actual reduction in the amount of space occupied by the fuel. The space required for engines and boilers is the same as

demanded on the coal-burner, the machinery being the same, but the space required for the oil fuel is only from 50 to 60 per cent of the space demanded by an equivalent amount of coal. There is some reduction possible also in fire-room space, because less room is required for stoking oil-fed engines.

7. A very important corollary of the above is the resultant ability of the vessel to carry more fuel on a voyage and reduce the number of stops. In other words, either the steaming radius of the vessel is considerably increased or the possible speed is augmented. For example, fast travel between Europe and the Antipodes has been hitherto restricted because of the inability to carry enough fuel to maintain the desired speed; oil obviates this difficulty. With a supply of reserve fuel, furthermore, the vessel is given some option as to where purchases shall be made and can buy oil where it is cheapest, but for the coal-burning vessel certain coaling ports on given voyages were necessities. The lack of bunkering facilities in foreign waters also placed this country under obligations to foreign nations.

8. The cost, delay, and waste of starting and hauling the fires of coal-burners is largely eliminated.

9. The working force required is greatly reduced by dispensing with nearly all the firemen and eliminating coal passers. The higher wages paid on American vessels made this an important factor.

10. The oil-burning vessel derives an advantage also from current measurement rules. Under the Danube rule the fuel space is estimated to be a percentage of the engine space and if theoretically coal would require 50 per cent of the engine space oil as fuel would require only 25 per cent of such space. Nevertheless, the deduction from gross tonnage for propelling power would be the same — 1½ times the engine space. Under the percentage rule the oil-burner also benefits. The deduction is 32 per cent of the gross tonnage of the vessel and this gross tonnage (and consequently the deduction) is increased by the oil carried in double-bottom tanks. Along with the greater deduction, however, goes a smaller amount of space actually utilized for fuel and as a result the ratio of cargo capacity to net tonnage is increased.

Eight years ago at the London Oil Congress a speaker showed the resultant economies from the substitution of oil for coal on the transatlantic liner *Mauretania*. This vessel consumes about 600

tons of coal per day, fed by hand at the rate of 25 tons per hour, so that a round trip requires a provision of about 11,000 tons. By the use of oil about 3300 tons of liquid fuel would be substituted for the coal, all of which could be carried in double-bottom tanks and the space otherwise occupied released for cargo. Assuming that $5 a ton could be earned on cargo the receipts would be increased by at least $30,000. But in addition, by mechanical firing the stokehold force could be reduced from 312 to 30 men, a force adequate to attend to the oil-burners and regulate the feed water, releasing space for about 200 third-class passengers. At $25 per head this would add $5000 to the income. Furthermore, with coal firing it is necessary to draw about 32 of the 192 furnaces every watch to remove clinker and for general cleaning, so that the aggregate energy is reduced from 68,000 horse power to 58,000 horse power. By oil the steam-raising capacity would thus be increased over 15 per cent, which would save 8 or 10 hours in the voyage. At present a large force is required to bunker the coal, and 20 hours of time are consumed in the process, while with oil the fuel required can be taken on in 6 or 8 hours without dust or noise. This excellent forecast of the benefits of oil has recently been strikingly verified by the Cunard liner *Aquitania* covering the last 129 miles of a voyage at a speed of 27.4 knots, which exceeds the best previous record by over one knot per hour, and the reduction of the schedule of the *Olympic* to one round trip every three weeks. The *Aquitania's* performances with coal fuel had never come up to the builder's expectations and the reduction of the *Olympic's* schedule would have been impossible with the fuel previously used.

Disadvantages of Oil Fuel:

1. While its cost is from two to five times that of coal it is less than 50 per cent more efficient. The factor of cost will, therefore, be an important influence in its use.

2. While coaling stations have been built to supply the needs of commerce, it will be some time before supplies of oil are situated so as adequately to meet the needs of ocean vessels. It was necessary for the Shipping Board to establish additional stations during the war in the United States in order properly to supply the oil-burning vessels in use, and the Director of Operations of the Shipping Board now states that the volume of fuel oil earlier

referred to must be produced and transported in special carriers to select places around the world, failing in which our ships become as useless as "painted ships upon a painted ocean."

3. The substitution of oil for coal merely affects the fuel and not the mechanism through which this is translated into energy, whereas internal-combustion engines utilize new mechanical principles as well as the advantages of the material.

Internal-Combustion Gas Engines

These may be divided, with reference to the fuel used, into two classes: (1) engines operated with gasified gasoline, naphtha, kerosene, or other light refined oils; (2) engines operated with producer gas.

The former group may be dismissed from consideration as being familiar to all and suitable at present only for small boats, where the cost can be ignored in view of the elimination of the cumbersome steam plant.

Producer-Gas Engines.—The principal parts of the engine are the producer, the scrubber, the drier, and the cylinders. Producer gas is the gas obtained by the partial combustion of fuel, usually coal, in a gas producer, a current of air mixed with steam or water vapor being passed through a deep bed of fuel in a closed producer. After burning is once started in the producer the air current serves to keep the process of combustion continuous. Producers are generally classified in two groups. In *suction* producers the draft through the producer is created by the suction of the engine. In *pressure* producers the draft is created by some form of blower, which raises the pressure at the entering side or end of the fuel column. The gas driven off by the producer is passed through the scrubber, where it is cooled and purified and thence to the drier, where it is dried and fed to the cylinders of the engine.

The gas is consumed in the cylinder, as in the Diesel oil engine, described later, but by reason of its gaseous form this consumption takes the form of an explosion. The ignition producing the explosion is supplied by an electric spark or a hot bulb in the cylinder. The cylinders of the producer-gas engine are larger than those required for gasoline. The engine may be of either the four-cycle or two-cycle type.

Advantages of the Producer-Gas Engine:

1. Its chief merit is the economy with which it is claimed the gas can be produced, since all grades of coal and even peat may be used as fuel. On the other hand, it is claimed that the best results are obtained only with anthracite and the advantage in cost consequently considerably dwindles.

2. A reduction in the amount of coal consumed as compared with the coal-burning vessel.

3. A reduction in the amount of space required for fuel as compared with the steamer, although it shows no saving as compared with the internal-combustion oil engine.

4. It requires less space than the steam engine because the space required for the producer is only about one-third that necessary for a water-tube boiler and one-eighth that required for a Scotch boiler.

5. Some reduction is accomplished in the number of attendants required as compared with the coal-burning ship.

Disadvantages of the Producer-Gas Engine:

1. The economy in fuel is considerably reduced if anthracite or other expensive coal is required to obtain the best results. Greater economy is obtained from the Diesel engine if the price of oil does not rise too high.

2. No saving in the weight or space required by the engine is obtained, whereas the internal-combustion oil engine furnishes a considerable saving. A much greater saving in cargo space and consequent increase in earning capacity is possible with the latter.

3. By reason of the gas producer required a greater crew is necessary than for the operation of an equally powerful Diesel engine.

4. Greater difficulty has been encountered in reversing the gas engine than the Diesel engine and this was one of the principal problems of the latter type.

The Internal-Combustion Oil Engine

Of these the Diesel and a group of engines known as semi-Diesel engines are most used. Dr. Rudolf Diesel, a German engineer, after experimenting a number of years completed an experimental engine in 1893. A patent was granted him in the

United States in 1895, and up to 1902 the principle was applied solely to stationary engines, many of which were in successful operation. About 1908 the first large Diesel marine engine was installed to convert a large passenger steamer on Lake Zurich, Switzerland, into an internal-combustion vessel, and about 1910 the first ocean-going vessel of any size was so equipped — the *Vulcanus*. This is a 1000-ton Dutch tank ship fitted with a 450-horse power engine. In 1911 there were 365 vessels equipped with Diesel marine engines and since that time the number has increased much more rapidly, but figures of the extent of present use are difficult to secure.

Operation of the Diesel Engine.— Using the four-stroke cycle as an illustration, the operation of the Diesel engine may be described as follows:

A suction stroke draws a supply of air into the cylinder and by a compression stroke of the piston this air is compressed with a consequent rise in temperature sufficient to ignite a gaseous vapor were one present. At the end of this compression stroke, by which the pressure has been increased to about 500 pounds per square inch, oil is sprayed into the cylinder. Since this injection must take place at a higher pressure than that obtaining in the cylinder it is performed by an air blast fed from a small reservoir charged to a pressure of 750 pounds. An air compressor is necessary to start the engine. The introduction of the fuel might be compared to the spraying of a solution by an atomizer and the high temperature in the cylinder causes immediate combustion, resulting in a power stroke. The fourth period in the cycle expels the burned gases. The maximum temperature within the cylinder is about 2500 degrees Fahrenheit, but since no metal now known would withstand such heat the parts subjected to it are surrounded by a water jacket for cooling purposes. The work performed by the engine may be regulated by changing either the quality or quantity of the mixture injected into the cylinder or by a combination of these methods. The former is usually employed in the Diesel-type engine. The ignition in the straight Diesel engine is the result of the high compression of air. A hot tube in the cylinder, supplied with heat from an outside source, an electric spark or a hot bulb of cast iron in the cylinder would produce similar results, the latter being sometimes spoken of as a semi-Diesel engine. It is evident that the internal-combustion engine decidedly

differs from the steam engine, whether the latter operates with coal or oil as fuel. In the steam engine the energy is received by the engine ready-made; in the internal-combustion engine the engine must produce its own energy. In the steam engine the combustion takes place in the furnace and the results are transmitted to the cylinders; in the internal-combustion engine the combustion takes place in the cylinder itself. The internal-combustion oil engine consumes liquid fuel while the internal-combustion gas engine requires gaseous fuel.

Several different methods have been adopted for reversing the direction of the screw propeller relatively to the engine, among them the following:

1. In small vessels to turn the screw propeller itself on the hub, thus temporarily converting a propeller with a right-hand pitch to one with a left-hand pitch or vice versa.

2. To use a propeller shaft which is detached from the crank shaft of the engine. Both shafts are in the same straight line but the actual physical connection is made by a clutch and gearing.

3. To join the propeller shaft and engine shaft and change the rotation of the engine as a whole by manipulating the engine for the moment by an independent supply of compressed air or by premature ignition and combustion.

Both four-stroke cycle and two-stroke cycle Diesel engines are used for marine work. In the four-stroke cycle there are a suction stroke, a compression stroke, a power stroke, and an exhaust stroke. On the suction stroke a supply of gas and air is taken into the cylinder through an inlet valve. On the compression stroke the intake of mixture ceases, the charge in the cylinder is compressed and at the end of the stroke ignition occurs. On the power stroke the temperature and pressure of the gas increase suddenly, due to combustion, drive the piston out and return to original conditions. On the exhaust stroke the refuse of the burned gases is expelled. In the two-stroke cycle there are a working or expansion stroke and a charge or compression stroke. The first stroke compresses the air which has been forced into the cylinder by a scavenge pump. Fuel is injected, combustion takes place, and the working stroke follows. During the second stroke the scavenge pump expels the burned gases through the exhaust and refills the cylinder with fresh air. Both types have their adherents, both are being experimented with, and both have their

advantages and disadvantages. The four-stroke cycle develops high speed at low cost, especially for small engines and, in addition, is of simpler construction. Its disadvantages are said to be a varying torsional movement, heavy flywheel, small specific output, large dimensions and the contamination of the new charge by burned gases. It is claimed for the two-stroke cycle that its specific output is larger than that of the four-cycle, that the size of the engine is only one-half that of the four-cycle for the same output, the elimination of valves by ports in the cylinder walls, more uniform torsional movement and ease of reversibility. It is admitted, however, that this type has greater frictional resistance and lower mechanical efficiency, lower speed, larger heat losses during the power stroke and complications in scavenging.

Advantages of the Internal-Combustion Oil Engine:

1. We have previously mentioned the greater steaming radius attained by steamers on oil fuel. With the greater engine efficiency supplied by the Diesel principle this radius is still further increased. The tanks of large vessels will give a cruising radius of 25,000 miles, sufficient to go around the world, passing all fuel stations. One vessel is said to have attained three times its former cruising radius with the same bunker capacity as for coal.

2. The advantages of oil as fuel previously mentioned are, of course, all present in the Diesel engine, including the cleanliness, the facility of fueling and transshipping fuel, the preservation of fuel compartments, and the saving in labor and time in taking on fuel.

3. Diesel engines develop power at less cost when oil does not cost more than three or four times as much by weight as coal, due to the fact that the weight of fuel required is approximately only one-fifth of that required for a steam plant of equal power. Reference is made later to the saving in weight and volume of fuel.

4. Economy in space is effected in two directions: engine and fuel. The saving in engine space is the result of the elimination of boilers, light and air shafts leading to the boiler rooms, and the smoke funnels. The saving in space may be roughly estimated at from 20 to 33 per cent of the space required for steam engines. In particular vessels a saving of as high as 50 per cent has been claimed. In this connection it should be remembered that the measurement rules offer no incentive for reducing the engine-room

space below a given proportion of the gross tonnage because of the system under which deductions are allowed — this is fully discussed in the section on measurement. As regards fuel, not only is less storage space required for oil, ton for ton, but double-bottom tanks are available for storage, releasing portions of the vessel for other purposes. In general, it may be said that the oil occupies only from 20 to 30 per cent of the space required for an equivalent amount of coal. In the first large vessel equipped with Diesel engines, a passenger steamer on a Swiss lake, the fuel-carrying capacity was said to be increased tenfold. This saving in fuel space required is one of the greatest economies of the Diesel engine.

5. Economy in weight; here again a saving is effected in both engines and fuel. The average saving in weight due to the engine is 100 tons. One writer states that the "approximate saving in weight for a 1500 shaft horse power installation (slow-speed Diesel engine of ordinary type adapted for cargo vessels) is somewhere in the neighborhood of 150 tons in favor of the Diesel engine as compared with the steam equipment, and approximately the same ratio applies for larger powers." As regards fuel there is a possibility of saving from 70 to 80 per cent in weight, Of two similar British cargo vessels it was found that one gained 200 tons because of the saving in weight of fuel when equipped with Diesel engines. A vessel of 2500 to 3500 tons displacement propelled by a steam engine of 1100 or 1200 indicated horse power would require 15 tons of coal per day, while a Diesel engine would require only 4 tons of oil. If the vessel bunkered for 20 days this would mean a saving of 220 tons. Allowing for the placing of oil in less accessible places there would be an additional saving in cargo space. In the pioneer Diesel-engined lake steamer referred to above there was a saving of 33 per cent in weight with an increased speed. This is especially important for dead-weight carriers where displacement is of primary importance.

6. Naturally, as a consequence of the savings referred to above, there result (1) an increased dead-weight capacity, (2) an increased space for cargo; or in other words, an increased potential earning power for the vessel. The net saving effected depends upon the construction of the vessel and the effect of measurement rules. One writer states that an extra cargo can be carried equal to about 15 per cent of the displacement of the vessel. In the

Jutlandia, of 5000 tons displacement, a gain of 20 per cent in freight and passenger space resulted from Diesel engines; in the *Seelandia,* of 10,000 tons displacement, a gain of 1000 tons of cargo was obtained. A cargo vessel of 5550 tons fitted with Diesel engines was found to have an extra freight-carrying capacity of 280 tons as compared with a sister ship fitted with steam engines. It is probable that 10 per cent increase in freight-carrying ability is a conservative estimate. In a 7000-ton vessel it was reported that the gain was as high as 800 tons.

7. In connection with the actual increase in cargo-carrying capacity described above it must be pointed out that the Diesel-engined vessel derives a very great advantage from the measurement rules and consequently in the payment of dues and taxes which are levied on the basis thereof. The same rules are applied in deducting the engine and fuel space from the gross tonnage as for steamers, whereas the space actually occupied is much less and the carrying capacity is much greater. This will be more fully appreciated after examining Part II of this volume.

8. The safety of the vessel, crew and cargo is increased by the Diesel engine through the elimination of stored-up energy which might inflict damage by explosion.

9. The Diesel engine is not subject to the disadvantages incidental to the necessity for an adequate and satisfactory water supply.

10. The internal-combustion engine is ready to start without the steam engine's delay in getting up pressure and the expenses of operation stop when the engine stops. No useless energy is consumed in keeping up fires and no potential power is lost by furnaces being cleaned.

11. A higher thermodynamic efficiency is developed by the Diesel engine, sometimes as great as 30 per cent.

12. Another very important saving with the Diesel engine is in labor cost. This economy is obtained by the absence of boilers, condensers, and other accessories in a steam plant which require attention. The labor-saving in the case of the *Mauretania* by the substitution of oil for coal will be remembered. The following table is given as an illustration of the saving by the Diesel engine in the case of a Pacific Coast vessel 425 feet long, carrying 10,000 tons of cargo on a voyage from San Francisco to Australia and return. There is, therefore, in the Diesel engine vessel as com-

pared with the oil-burner, a saving of five men, their subsistence, their quarters, the care of their linen, and the additional help in the steward's department, or approximately $600 per month. To take a smaller vessel as an illustration, the motor ship *Apex*, operated between Puget Sound and Alaska, carrying cannery supplies and fish, carried only 3 engineers and 3 oilers with no firemen and no bunker men or wipers, as compared with a steam vessel similarly employed, which used seven additional men. This was a saving of approximately $700 per month in wages, and incidentally this vessel carried 275 tons more cargo and saved $2400 a month in fuel and oil as compared with the steam vessel similarly engaged.

CREW REQUIRED

For Diesel engine	*For* Oil-burning steam engine	*For* Coal-burning steam engine
1 chief engineer	1 chief engineer	1 chief engineer
3 assistant engineers	3 assistant engineers	3 assistant engineers
3 oilers	3 oilers	3 oilers
3 wipers	3 wipers	3 wipers
1 storekeeper	1 storekeeper	1 storekeeper
1 machinist	.....	.....
1 electrician	.....	.....
.....	3 firemen	9 firemen
.....	1 deck engineer	1 deck engineer
.....	3 water tenders	3 water tenders
.....	.....	3 coal passers
Total 13	Total 18	Total 27

13. The Diesel engine has also proved useful as an auxiliary engine in sailing vessels. One writer believes that it will prolong to some extent the existence of the large sailing ship. As a cheap method of conveying freight long distances the sailing vessel is undoubtedly valuable, but the great disadvantages attending its employment are the liability of becoming becalmed for days or even weeks, and the absence of reserve power at critical moments. With the auxiliary power, however, it is possible to make upwards of 4 miles per hour during the absence of wind and escape the calm zone.

In order to present the situation impartially the disadvantages of the Diesel engine are briefly presented:

1. The motor has to be started by an outside agency and auxiliary power must be accumulated from a previous running of the engine.

2. Hitherto the problem of reversing has been a serious one, and in some cases gearing must be introduced in the transmission machinery between the motor and its work.

3. It is most efficient at only one speed and to meet lower speeds must be geared down in order to secure power.

4. In the four-stroke cycle variety, there is but one power stroke in four piston strokes. Therefore, to secure uniformity in turning effort for each movement of the piston the number of cylinders has to be increased.

5. Upon interruption of the fuel supply or the ignition the engine stops short without warning.

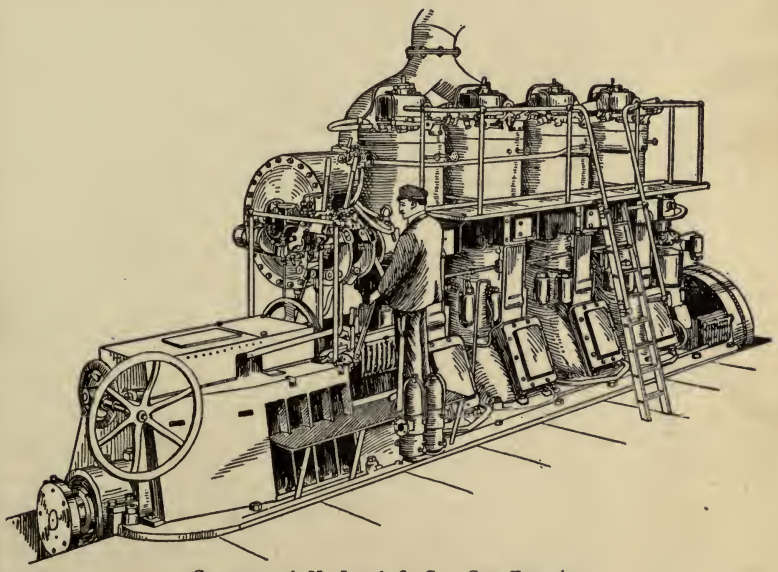
6. Lack of familiarity by engineers with the engines renders it more difficult to get a satisfactory crew.

7. The initial cost of installation has been greater than for steam engines, including the boilers.

8. Oil supplies are not so satisfactorily distributed over the world as coaling stations.

Fuel for Diesel Engine.— It is hardly an exaggeration to say that any kind of oil may be used in the Diesel engine. The only qualification is that for tar oils a special arrangement is necessary. The list of available fuels includes crude petroleum, residual mineral oils remaining after lighter oils have been distilled, tar or creosote oils, gasoline or petrol, naphtha, kerosene, alcohol, vegetable oils, and animal oils. Of these the first three kinds are preeminently important. Gasoline, naphtha and kerosene are too dangerous and too expensive for use in any except small boats where their convenience is an important consideration. Alcohol, vegetable oil, and animal oils are insufficient in supply, nonuniform in quality or dangerous. Crude oil and residual mineral oils are most used at the present time. Crude oil would be used to a greater extent were it not for the high value of the lighter oils which may be separated from it and the fact that the presence of volatile oils renders storage more dangerous. Tar or creosote oils, obtained by the distillation of coal or crude oil, are beginning to be rather extensively used, particularly in Germany, and may become a factor of considerable importance, though it is likely that crude and residual oils will retain first place.

Semi-Diesel Engines.— This name has been applied to engines constructed on principles slightly different from the Diesel engine. These are, in general, a compromise between the oil engine and the gas engine. Such vaporizer oil engines obtain their power by the combustion of oil vapor in the cylinder, as in the Diesel engine, but obtain ignition by an electric spark or a hot bulb and



Courtesy of H. Lund & Co., San Francisco

FIG. 54.— SEMI-DIESEL ENGINE

not by air compression alone. They differ from the Diesel engine in that they vaporize the oil, and from the gas engine in that they depend upon combustion and not explosion. They are claimed to produce perfect combustion, have a smaller initial cost, do not require expensive air compressors, and have a working pressure about one-third that of a Diesel engine. The engine is also claimed to be more flexible, the power not decreasing so rapidly when the engine is brought to reduced speed by an overload. The alleged disadvantages are higher fuel consumption and lower efficiency. Various types of semi-Diesel engines are produced by different manufacturers and an illustration of one type of such an engine is reproduced above:

REFERENCES

1. JOHNSON, E. R.: *Report on Measurement of Vessels for the Panama Canal.* Washington, 1913. Chap. X. (Brief description of the operation of internal-combustion engines and excellent discussion of their advantages and disadvantages.)
2. Articles by WILLIAM DENMAN, K. P. RADOVANOVITCH, L. K. SIVERSEN, G. A. DOW, J. H. HANSEN, and B. LLOYD. *Pacific Marine Review,* Feb., 1919. (Description of the efficiency of the Diesel engine and some illustrations of its application.)
3. "Bolinder Bulletin." H. Lund & Co. (Description of the semi-Diesel type of engine and its advantages.)
4. JOHNSON, E. R., and HUEBNER, G. G.: *Principles of Ocean Transportation.* D. Appleton & Co., New York, 1918. Chap. IV. (Brief description of internal-combustion engines and their advantages.)
5. ALLEN, P. R.: "Possibilities of the Internal-Combustion Engine Applied to Marine Propulsion." *Cassier's Magazine,* 1911, Vol. 40, pp. 705–736. (Description of internal-combustion engines in some detail, nontechnical, many illustrations and diagrams.)
6. CHALKLEY, A. P.: *Diesel Engines.* Van Nostrand, New York, 1912. Introduction, Chaps. II, VI, and VII. (Operation and efficiency of the Diesel engine. Technical in character.)
7. MORRISON, L. H.: *Oil Engines.* Mc-Graw-Hill Co., New York, 1919. (One of the later volumes on the subject, technical in character.)
8. MATHOT, R. E.: *Internal Combustion Engines.* Van Nostrand, New York, 1910.
9. *Encyclopedia Americana,* Article on "Internal-Combustion Engines."
10. O'DONNELL, E. E.: *The Merchant Marine Manual.* Boston, 1918. Pp. 124–132; 163–167. (Description of the operation of the oil-burning engine, diagram of the Diesel engine and description of its care and supervision.)
11. See also the bibliography published in Reference 1, page 220, and the current files of *Pacific Marine Review, The Marine Review, International Marine Engineering, Transactions of the Institution of Naval Architects, The Engineer, Proceedings of Institute of Marine Engineers, Journal of American Society of Naval Engineers,* and *Cassier's Magazine.*

PART II

THE MEASUREMENT OF MERCHANT VESSELS

CHAPTER VIII

KINDS OF TONNAGE AND THEIR USES

Various Meanings of Tonnage

There seems to be in maritime matters a greater tendency than elsewhere to use the same word in different senses, a tendency which necessarily promotes confusion and mistakes. Nowhere is this more evident than in the expression "tonnage," a term susceptible of at least five meanings in connection with the merchant marine, not to mention additional significance in the navy. The various kinds of tonnage may be classified as follows:

I. With Reference to the Object to Be Measured.— The ton as a unit of measurement is applied to:

A. *The Cargo Carried,* as a unit of weight ("weight ton") or of volume ("space ton").

B. *The Vessel,* also as a unit of either weight or volume, expressed as displacement, dead-weight or register tonnage. This application of the same unit in the measurement of several related objects itself causes confusion. For example, the expression "dead-weight tonnage" without qualification might be used to describe either the cargo or vessel, although the context usually makes the meaning in such cases clear.

II. With Reference to the Method of Measurement.— The "ton" as a unit of measurement may be employed to represent either *weight* or *volume.*

A. *Weight Tonnage,* in two forms:

1. Displacement Tonnage, or the Weight of a Vessel as Measured by the Weight of the Water Displaced. The ton, in this connection, is usually of 2240 pounds avoirdupois but may also signify a metric ton of 2204.62 pounds avoirdupois, a possibility which augments the confusion. Furthermore, displacement is used in more than one qualified sense as expressing (*a*) the weight of the vessel fully loaded, termed "displacement loaded" or "maximum displacement"; (*b*) the weight of the vessel without cargo or fuel, termed "light displacement"; and (*c*) the weight of the vessel

partly loaded at a given moment, intermediate between the two preceding weights, termed "actual displacement."

2. Dead-weight Tonnage.— This is a measure of the capacity of a vessel expressed in terms of the weight of the cargo, and the "ton" may again mean 2240 or 2204.62 pounds avoirdupois; usually the former. The "maximum dead weight" is the greatest weight of cargo the vessel can safely carry, while the "actual dead weight" is the weight on board at a given moment.

B. *Volume Tonnage, in three forms*

1. Gross Tonnage.— Every vessel is measured as a prerequisite to registration and gross tonnage is one form of register tonnage. It is a measure of the total "closed-in" space of the vessel, after certain exemptions from measurement have been allowed. The ton in this case represents 100 cubic feet of space, a figure which was taken as a measure of convenience and policy. When the present system of measuring was devised in England it was desirable that the results attained should not be radically different, for vessels in general, from those attained under the older measurement system. It was found that the tonnage under the old system aggregated 3,700,000 tons. By the new system of measurement the aggregate capacity of the British merchant fleet was found to be 363,412,456 cubic feet. The ratio of existing tonnage to new capacity was therefore 1 to 98.22, but for convenience this was taken as 1 to 100.

2. Net Tonnage.— Another form of register tonnage is the "net ton," also representing 100 cubic feet and obtained by a measurement similar to that employed for gross tonnage. The net tonnage of a vessel is the gross tonnage less deductions for space not utilized in earning freight and therefore is supposed to represent approximately the earning-power space of a vessel. Both gross and net tonnage depend upon the rules under which they are measured, rules which are far from uniform. The gross and net tonnages under different rules are therefore not exactly comparable.

3. Freight Tonnage.— Cargo is often measured on the basis of its volume instead of its weight. The freight "ton" in this case represents 40 cubic feet of space.

It is evident that with so many meanings attaching to the word "ton" its use necessitates considerable care to avoid misunderstanding. It is a convenient unit for a great many purposes.

Relations Between Various Forms of Tonnage

The relation of net tonnage to gross tonnage will vary according to (*a*) the measurement rules employed, and (*b*) the type of vessel. The following table shows the difference between net and gross tonnage under the various nations' measurement rules.[1]

Flag	Gross	Net	Per cent of net to gross
United States	1,439,911	939,505	66
Great Britain	17,940,862	10,893,898	61
Denmark	668,836	391,788	59
Netherlands	982,104	607,286	68
France	1,445,422	835,016	58
Germany	3,959,147	2,416,370	61
Italy	985,716	597,640	61
Japan	1,064,169	675,983	64
Norway	1,385,631	838,320	63
Russia	687,231	400,761	59
Spain	746,047	459,198	62
Sweden	756,909	449,872	60

This merely illustrates the fact that net tonnage is naturally a variable quantity under divergent measurement rules. While the ratio of net to gross tonnage of steamers ranges from 55 to 65 per cent of gross, the ratio for sailing vessels is about 87 per cent because of the absence of propelling engines and coal bunkers.

Naturally there is little relation between register tonnage and displacement. It is true, of course, that beyond a certain point additional strength and weight is necessary in order to attain a large gross or net tonnage but two vessels of similar displacements may vary widely as regards gross and especially net tonnage. Nor would the relation be of any particular commercial value if ascertained. A relation does exist between displacement and dead weight; since the displacement, loaded or actual, measures the weight of the vessel and cargo on board, while light displacement measures the weight of the vessel, the difference gives the dead-weight tonnage. This shows the capacity of the vessel if loaded entirely with heavy commodities.

[1] Adapted from "Report on Panama Canal Traffic and Tolls," Washington, 1913, 85. Figures are for 1910.

The only remaining relation to be considered is that between registered tonnage and cargo-carrying ability, and this involves the whole question of how accurately vessel measurement appraises the potential earning power of the vessel. Cargo may, in general, be divided into two classes, (1) that of great density and comparatively small volume, such as cement, pig iron, iron and steel manufactures, grain, coal, etc.; (2) that of relatively light weight and considerable bulk, such as package freight and general merchandise. Since, in general, the first type is charged for on the basis of weight and the second on the basis of space, a combination of both furnishes the greatest number of tons of paying freight. Heavy cargo would load the vessel down to the load line without fully utilizing the capacity, and light freight would entirely fill the vessel without bringing it to sufficient draft. A modern shelter-deck steamer can be loaded with measurement cargo exceeding in measurement tons its dead-weight capacity in weight tons. For example, a vessel of 4640 tons gross register tonnage has a dead-weight capacity of 8500 tons and can be loaded with 9500 tons of measurement cargo. Another vessel of the well-deck type has a gross tonnage of 5400, a dead-weight capacity of 8515 tons, and space for 8500 tons of measurement cargo. Loaded cargo steamers carry on the average about 2¼ tons of dead-weight freight for each net ton. The ratio of net tonnage, gross tonnage, and dead weight is as 1 to 1½ to 2¼. By combining weight and measurement cargo the ratio may be made 1 to 1½ to 2¾. An investigation in 1899 showed that the ratio of cargo tonnage to net tonnage of vessels, steam and sail, in the world's commerce was about 1¾ to 1. This smaller figure results from the many different trades included and the operation of vessels only partly loaded or sailing in ballast. The extent to which vessel measurement gauges the potential earning power is discussed more fully later.

Uses for Vessel Tonnage

This discussion will be divided into two parts; the first dealing with weight tonnage, in the form of displacement and dead-weight, and the second with measurement tonnage, in the form of gross and net register tonnage. Their uses are given here; their calculation in chapters IX, X, XI and XII.

I. Displacement and Dead-Weight Tonnage.—

A. *Statistical Purposes.*— The dead-weight ton is often used as a unit for the measurement of shipping and commerce, as illustrated by the following cases:

1. Comparison of the Merchant Marine.— While register tonnage is more frequently used for this purpose the dead-weight ton has recently achieved prominence by reason of its use by the Shipping Board during the World War. Thus, this was a common basis for describing the size of the fleet in operation, and the figures of overseas army transportation were kept by the War Department in a similar manner. The displacement ton, however, is the common unit of measurement for war vessels, and furnishes the legal measurement in Great Britain for this purpose. Thus when we say that Great Britain possesses the largest navy in the world we are referring to displacement tonnage.

2. Shipbuilding Comparisons.— The dead-weight tonnage is a common figure for the measurement of the extent and progress of shipbuilding. Its annual reports show that the maximum program of the Shipping Board up to June 30, 1919, was 17,399,961 dead-weight tons, of which 3,783,125 tons had been canceled or suspended, leaving a net program of 13,616,836 dead-weight tons. Of this 301,809 dead-weight tons were delivered in 1917, 2,987,377 in 1918 and 2,568,978 in 1919 or a total of 5,858,164, leaving 7,758,672 tons to be delivered.

3. Cost Comparisons.— The dead-weight ton is frequently used as a basis for comparing shipbuilding costs. We find cited in texts, for example, that "English yards would bid $37.50 per dead-weight ton against the lowest American bid of $55"; that "the bid in England would be $32 as against $50 in the United States." Labor costs and costs of operation are sometimes similarly compared. Thus, during the World War it was estimated that on vessels costing $215 per dead-weight ton the return on investment ought to be $5.10 per dead-weight ton per month, estimating depreciation at the rate of 10 per cent per annum for the first three years and 5 per cent thereafter on the estimated normal cost of $100 per dead-weight ton, amortization of 33⅓ per cent per annum for three years of the difference between wartime and normal costs, and interest at 5 per cent per annum.

This is merely cited as an illustration of the dead-weight ton used as a unit of calculation for statistical purposes.

4. Dead-weight Tonnage as a Basis for Conference Agreements.— Agreements respecting freight traffic for the purpose of regulating competition are common in the line traffic. These agreements sometimes provide for a division of the service and the profit between various lines, often on a tonnage basis. Thus it was shown by a Congressional investigation that the lines between New York and Australia had agreed to divide the trade between three lines, one furnishing 42½ per cent of the tonnage (presumably dead-weight), one furnishing 35 per cent of the tonnage, and one 22½ per cent. The profits were to be divided in similar proportions. Similar agreements have been found in other trades.

B. *Legal Purposes.*— The dead-weight and displacement ton is uncommon as a legal unit, but indirectly it figures as a basis for the proposed English freeboard rules in the calculation of the coefficient of fineness, the formula being 35 times the molded displacement in tons at a molded draft which is 85 per cent of the molded depth of the freeboard deck divided by length times breadth times the above draft. The use made of this formula is described in the next chapter.

C. *Taxation Purposes.*—

1. Tonnage Taxes.— Dead weight has served in the past as a basis for the assessment of tonnage taxes levied for the use of navigable waters and port facilities but has largely been replaced by net registered tonnage. An Admiralty committee in England in 1821 held that dead-weight capacity was the fairest basis for tonnage, and early English rules measured dead-weight tonnage, rather than internal volume. Displacement has been urged also as a measure of a vessel's capacity and was discussed in the Report of the Tonnage Commission of 1881.

2. Tolls.— Both dead-weight and displacement tonnage have been suggested as a basis for the assessment of tolls levied on merchant vessels for the use of canals and river improvements but have never been favorably considered for this purpose, all the prominent canals having adopted register tonnage for this purpose. On the other hand, the Panama Canal rules have adopted displacement tonnage as the fairest basis for the levy of tolls on warships. Net registered tonnage is a misused term in connec-

tion with these vessels because it indicates the earning capacity of a vessel and the warship is designed as a whole for a particular purpose. Furthermore, the system of measurement in use is designed for merchant vessels and to apply it to war vessels is a cumbersome process. The Suez Canal uses it for this purpose, but the actual measuring is done by the respective nations owning the vessels. The rules give a widely fluctuating ratio of net tonnage to normal displacement, showing their highly accidental results. Displacement tonnage has the advantage of being easily determined by a comparison of the draft of the vessel and its "displacement curve," described in the next chapter. Mr. R. H. M. Robinson, a naval expert, testified that:

> The displacement of a warship is the most accurate means of estimating the value of that warship or the power of that warship. It is not an absolutely accurate measurement, but it is the most accurate measure you could name. If a ship has 20,000 tons displacement it is reasonable to presume that it is twice as valuable from the military standpoint as a 10,000-ton ship.

It is also considered a standard which is reasonably fair as between different classes of warships. The Panama Canal tolls have been fixed for such vessels at 50 cents per displacement ton.

D. *Charges for Services Rendered.*— Dead-weight tonnage occasionally may serve as a basis for charges for services rendered to a vessel entering, leaving, or lying at a port; displacement is never used for this purpose though it has been proposed as a basis for the levy of dock charges.

1. Pilotage Fees.— Dead weight or displacement seldom serves as a basis for pilotage fees except indirectly as a factor in the draft of the vessel. It is mentioned in this connection, however, by foreign writers. The same is true of services rendered.

E. *Description of Vessels.*— Displacement is frequently used in this connection for war vessels, as previously indicated, though it has many limitations. Dead weight is important for cargo vessels.

1. In Shipbuilding.— One of the most important factors in the building of a vessel is the dead-weight tonnage. With this given to the designer as a basis, he proceeds to figure the type of vessel which will be the most economical for the trade and which will have the lowest possible legal tonnage.

2. Carrying Capacity.— For vessels engaged in the carriage of heavy commodities dead-weight tonnage serves as an approximate measure of size and capacity.

3. For Chartering.— In ocean charters it is common to base the remuneration for the hire of the vessel upon the dead-weight tonnage of the vessel. Thus the United States Shipping Board paid from $5.75 to $7 per dead-weight ton per month for vessels requisitioned for government purposes. The shipbroker may also estimate the availability of vessels for definite purposes on the basis of their dead-weight capacity.

4. As a Basis for Calculations.— It is shown later that displacement tonnage may be used as a means of calculating cargo on board and cargo discharged, and we have seen that from the loaded displacement and light displacement dead-weight tonnage is found.

II. Gross and Net Tonnage.—

A. *Statistical Purposes.*— The most widespread use of register tonnage is as a unit for statistical purposes. The primary object here involved is to have some common denominator to which the volume of commerce and shipping of different years and different countries may be reduced for purposes of computation and comparison. This object is very imperfectly fulfilled by the register ton as at present constituted. The word "ton" is susceptible of different meanings and confusion, the system of measuring is not uniform throughout the world and the spaces measured are not the same in different countries and under different rules. Nevertheless, this is the only statistical unit at present available.

1. Register Tonnage and Comparison of the Merchant Marine. — Thus, on June 30, 1919, the Commissioner of Navigation reports that American shipping had grown from a gross tonnage of 7,928,688 in 1914 to 12,907,300 in 1919. Even in this comparison of different years in the same country defects in the unit of measurement are apparent. Subsequent to 1915 shelter-deck spaces and closed-in spaces were more liberally treated than previously, and while the difference between 1914 and 1916, for example, is probably not great the figures are not theoretically comparable. How much greater is the discrepancy when we attempt to make a comparison between the net tonnage of 1919 and 1890 at which earlier date a different ruling for propelling-

space deductions was in force; or between the gross tonnage of 1919 and 1860, at which earlier date the Moorsom system of measurement had not yet been adopted. In his report for 1919 we find also a comparative table of steam and sail tonnage on the basis of gross tonnage. A comparison of net tonnage for the two classes is not satisfactory because of the deductions made in steam vessels for space occupied by engines. Strictly speaking, the proportion of steam gross tonnage to total gross tonnage in 1910 and 1919, for example, would not be comparable because of slight changes in the rules. These comparisons become much less exact when made between the merchant fleets of different countries, a purpose for which tonnage is also used. Thus we find that Lloyd's Register reports the gross and net tonnages for various countries and for a series of years, but comparisons between countries are evidently inexact, since the national rules all differ. Time comparisons are likewise inaccurate because modifications in rules have been constantly occurring. For example, the rules affecting net tonnage in the United States, Germany, Russia, Holland, France, and Spain were all changed between 1895 and 1904. In spite of these limitations the indefinite register ton remains the only available unit and therefore must be employed for these purposes.

2. Register Tonnage Employed as a Measure of the Extent and Progress of Shipbuilding.— Thus, to give an idea of shipbuilding progress in the United States we say that the average monthly gross tonnage built was 27,000 in 1916, 86,000 in 1917, 227,000 in 1918, 311,000 in 1919, and 308,000 in 1920. Comparisons are similarly made between the various countries of the world.

3. Register Tonnage Used for Comparisons of Trade and Shipping.— For example, while figures for the imports and exports of commodities are given in terms of dollars no complete tabulation is made of their amount. Statistics are kept, however, of vessel entrances and clearances in terms of net tonnage, and we can ascertain that nearly 48,000,000 tons cleared from American ports in 1919 and nearly 45,000,000 tons entered. It is also possible to ascertain from the figures that of the tonnage entered and cleared 44 per cent was American and 56 per cent foreign. An interesting application of this type of statistics is shown in the estimate of the probable increase in traffic through the Panama

Canal, as an important factor in fixing the rate of toll. The tonnage which could have used the canal to advantage in 1899 and 1910 was ascertained from vessel entrance and clearance figures and from the increase so divulged the probable increase from 1910 to 1915 was estimated. The actual tonnage fell considerably short of the estimate. In figures of vessel entrances and clearances not only is the divergence in net tonnage a disturbing factor but in addition it must be recognized that the methods of recording such statistics are far from uniform. In the United States and Great Britain entrances are credited to the first foreign port from which the vessel sailed. In Italy when a vessel comes from more than one foreign country it is credited to each country. The entrance methods of the United States and Great Britain are similar; the rules for crediting clearances are different. We credit the clearance to the first foreign port of discharge unless the bulk of the cargo is destined elsewhere, while vessels leaving Great Britain are credited to the last port to which cargo is consigned. In 1910 in the United States itself four variations in the methods of compiling these figures existed. It may be said that there are unavoidable duplications and omissions when considering movements to and from particular countries and over particular trade routes.

4. Comparisons of Financial Results.— It is sometimes convenient, for purposes of comparison, to reduce financial results to a vessel ton basis, or to make comparisons between financial results and vessel tonnage. Thus, since ocean freight rates and charter rates depend upon supply and demand of transportation, an explanation of existing rates and judgment of future rates inevitably include a consideration of available vessel tonnage. Profits of shipping companies may be compared on a tonnage basis and costs are sometimes also figured in this manner, though more frequently the dead-weight ton is used.

5. Conference Agreements.— Agreements and combinations among otherwise competing steamship lines are common, the old fallacy of absolutely unrestrained competition on the ocean having been thoroughly disproved. We have previously shown the application of tonnage statistics to freight agreements between the lines. Before the World War a passenger, agreement existed governing the steerage passenger traffic between the United States, Great Britain, and a portion of Europe, the provision of which was

that each line agreed to arrange its services so that the number of steeragers carried corresponded to the number allotted to it by the agreement. The lines furnished to the secretary a statement of passengers carried and tonnage used, from which the secretary prepared monthly accounts to show how the lines stood to each other with regard to tonnage employed. For every increase of 1000 tons (presumably net tonnage) each line was allowed a certain number of steeragers, resulting from each 1000 tons of the total tonnage employed in the current year by all the lines. The increase in tonnage was counted for 70 per cent and the decrease in tonnage also counted as 70 per cent if the tonnage did not decrease more than 10 per cent. The agreement thus allowed the profitable lines to increase their tonnage in the proportion that the trade showed justified.

B. *Legal Purposes.*— The ton unit, having been widely used for commercial purposes, also became a commonly accepted criterion for many legal purposes.

1. Licenses.— For example the general navigation laws of the United States require that vessels in the foreign trade be registered, a prerequisite to obtaining a register being the measurement of gross and net tonnage. Vessels of 20 tons or upward engaged in the coasting or fishing trade are officially enrolled, while those of 5 tons but less than 20 tons are licensed. Measurement and determination of net tonnage is a universal requirement for the official recognition of a vessel's status, and in practice the ship's tonnage papers are essential documents for foreign trade.

2. Subsidies and Bounties.— Tonnage frequently serves as a basis for government aid to shipping and shipbuilding. Thus, France pays $27.99 per gross ton to iron and steel vessels constructed at home and $18.34 to sailing vessels so constructed. Under the law of 1906 equipment bounties are paid which depend on the tonnage of the vessel, days in commission, character of propelling power, speed, quantity of cargo, and average daily run. For steamers the grant is 4 centimes per ton per day for the first 3000 tons, 3 centimes additional for each ton between 3000 and 6000 tons, and 2 centimes additional for each ton between 6000 and 7000 tons. These are increased for vessels of 14 knots and over. In Japan construction bounties are granted on large vessels on the gross tonnage basis and general navigation bounties on the same basis. The Austrian law of 1893 pro-

vided for subventions based on net tonnage, but most modern laws are based on gross tonnage. If the subsidies based upon gross tonnage are large enough the natural tendency is to attempt to enlarge the gross tonnage of vessels entitled to subsidies on this basis, as the subsidies received more than compensate for any extra tonnage taxes and port charges so incurred.

3. Limitation of Damages.— To prevent small vessels from being assessed with damages out of proportion to their size in cases of collision where their responsibility would otherwise so result, laws are found which limit the liability. In the United States the extent of this limitation is the value of the vessel and the freight money earned on the voyage, but in England the legal limitation is fixed at 8 pounds sterling per gross ton in the event of property damage and 7 pounds sterling per ton additional if there be loss of life or personal injury. The legal liability is virtually fixed, therefore, on the basis of the tonnage and not the value of the vessel.

4. Tonnage as Evidence.— Inasmuch as custom has made the registered tonnage a common method of estimating the size and capacity of vessels the courts have been moved to recognize and infer registered tonnage where the expression "ton" has been used without qualification. Thus, an ordinance of the city of New Orleans required ocean steamships arriving "from sea" and landing at any city wharf to pay from 15 to 20 cents per ton wharf dues. The court said in the *Thomas Melville*, 62 Fed. 751, "The word 'ton,' in the ordinance and amendments thereto controlling this case, as applied to the measurement of vessels, has a certain definite meaning, well settled by custom and by the navigation laws of the United States, and it means 100 cubic feet of interior space."

5. Classification for Legislative Purposes.— It is common to use gross tonnage as a measure to distinguish vessels of different sizes in legislative acts. Thus, for example, steamers of over 700 gross tons carrying passengers for hire may be required to have hull and boilers inspected by the government. In subsidy and subvention acts the grants to vessels are sometimes classified in accordance with the size of the vessel on this basis.

C. *Tonnage as a Basis for Taxation.*— Tonnage from the earliest times has served as a basis for taxation. This was, in fact. the origin of the measurement of vessels in England and has

now become a world-wide factor in determining vessel construction and net register tonnage.

1. Tonnage Taxes.— These taxes are universally levied as a charge for the use of the navigable waters under national jurisdiction, though they may to some degree be regarded as a compensation for the service of maintaining the safety and convenience of a port. We distinguish such taxes from charges for services rendered, which are discussed later. While tonnage taxes are assessed at practically all ports of the world it is sufficient for the purpose of illustration to confine attention to the United States. Here the power of the federal government over foreign commerce and the specific prohibition of the Constitution against tonnage and customs duties without Congressional consent precludes the states from exercising such tonnage taxation. Prior to 1882 the federal government levied a tax of 30 cents per annum per gross ton on vessels entering American ports from abroad. In 1882 tonnage taxes were placed upon a net tonnage basis, and at present a tax of 2 cents per ton is imposed upon all vessels entering from ports in North America, Central America, West Indies, Bahama or Bermuda Islands, South American Coast bordering on Caribbean Sea or Newfoundland, and a tax of 6 cents per ton on all vessels entering from other foreign ports, irrespective of ownership. It is not levied on more than five entries during any one year at the same rate, and laws exist which permit reciprocal arrangements with foreign nations which agree to exempt or partially exempt our vessels from similar taxation. The navigation laws provide for alien tonnage taxes on vessels of nations which discriminate against the United States of from 30 to 50 cents per ton. A state may levy a tax upon the property of its citizens, including vessel property, but not upon registered tonnage. Without taking space to consider the various court decisions respecting federal and state taxation powers, it may therefore be rather crudely stated that "tonnage" has become practically a term distinctive of federal taxation through decisions preventing states from levying taxes on this basis. A statute of Maine provides for the assessment of sailing vessels on the basis of an arbitrary value per gross ton, decreased annually with the vessel's age. Indiana requires owners of vessels to pay an annual tax of 3 cents per net registered ton *in lieu of all other taxes*, and Minnesota has a similar law. The states

regard these laws as property taxes and not tonnage laws. As previously stated, such tonnage taxes are found in other countries also. For a discussion as to whether register tonnage is an equitable basis for taxation see the chapter on net tonnage.

2. Tonnage as a Basis for Tolls.— In addition to charges for the use of ports, vessels using canals are ordinarily subjected to the payment of tolls. Such tolls are in some cases practically a charge for services rendered, designed to make the canal self-supporting, and in others yield a profit. All merchant vessels using the Panama Canal are charged $1.20 per net ton by Panama rules, with a deduction of 40 per cent for vessels in ballast, subject to the limitation that the tolls shall not exceed $1.25 per net ton as calculated under United States measurement rules. For the use of the Suez Canal the toll on merchant vessels was $1.21 per net ton, but this figure was increased during the World War until the rate reached $1.64 per net ton. These tolls yield a handsome profit. The Kiel Canal connects the North and Baltic Seas, and for its use prior to the World War tolls on net tonnage according to the size of the vessel were charged. These ranged from .6 mark per net register ton for the first 400 tons to .2 mark per ton for each ton above 800 net tons, with a minimum of 10 marks per vessel. The Corinth Canal connects the Gulf of Corinth with the Gulf of Aegina. The toll charges are based on net tonnage and vary with the type of vessel and the route over which it operates. Tolls are also collected by private companies and the states for the use of river improvements and canals, usually on the basis of tonnage.

D. *Tonnage as a Measurement of Services Rendered.*— In addition to taxes a vessel is put to additional expense for various services rendered at a port. The value of these services to the vessel is usually gauged by the size of the vessel as determined by its tonnage.

1. Pilotage Fees.— This includes the charges for bringing the ship in or out of a harbor or through a channel. At the port of Boston this charge is based on the draft of the vessel and the net tonnage, being $5 per foot for vessels over 2000 net tonnage. Ordinarily, however, such charges in the United States are based simply upon draft. In France, pilotage fees often depend solely upon net register tonnage.

2. Towage Charges.— These are charges for the employment

of tugs or towboats required to assist vessels into and out of the harbor, for docking and undocking or for moving the vessel from pier to pier. At Philadelphia this charge varies with the gross tonnage of the vessel and the service rendered and at Savannah the charges range from 17 to 20 cents per gross ton for towage to and from sea. The towage charges at San Francisco are regulated by the net tonnage of the vessel. Towage charges are also assessed for passages through canals, but not usually upon a registered tonnage basis.

3. Dockage Charges.— These include all charges levied against vessels for the use of berthing space, for loading, discharging, repairs, etc. At public piers in New York, for example, the charge is 2 cents per net ton up to 200 tons and ½ cent per ton for the excess. At Philadelphia public piers the charge is on a similar basis. At New Orleans these charges are on the basis of gross tonnage. As an alternative, at some docks wharfage is charged — a charge based upon the amount of cargo passing over the dock or wharf.

4. Quarantine Charges.— The states often impose quarantine charges to defray the costs of protecting the health of its citizens, and such charges are sometimes regulated by the vessel tonnage. Thus, at the port of New York a vessel of over 500 tons gross from a foreign port pays a fee of $10 while one of 500 gross tons or less pays a fee of $5. Other vessels are charged fees for fumigating and disinfecting of $10 for each forecastle and 2½ cents per net ton for vessel holds.

5. Insurance Premiums.— In Great Britain and recently in the United States mutual protective associations have been formed to insure members against the liability of a vessel-owner for damage to the cargo in his possession due to negligence, for injuries to persons through the acts of the owner or his agents and the liability under the bill of lading. Each owner enters his vessel in the association and pays a fixed rate per ton for the protection afforded.

E. *Description of Vessels.*— Tonnage is frequently used as a means of describing and comparing individual vessels and their attributes.

1. Comparison of Vessels.— We find, for example, that the progress in shipbuilding in the North Atlantic trade may be approximately indicated by a diagram of the gross tonnage of the

prominent vessels constructed for the route. Register tonnage is also a convenient method of indicating the relative sizes of two vessels, though we shall find later that it is not a very definite one.

2. Tonnage Comparisons.— Interesting comparisons are frequently made between register tonnage and displacement, register tonnage and dead weight, and register tonnage and cargo tonnage. These are usually of value only when all the details for the comparison are available, owing to the many individual circumstances which may affect the result. For this reason such comparisons are of little general value.

3. Register Tonnage as a Basis for the Building, Hire, or Purchase of Vessels.— Thus a price may be agreed upon per net or gross ton. For example, in ocean trade it is common for the owner of a vessel to furnish the crew and provisions of a vessel and to hire it to a charterer, the latter paying for the fuel and port expenses and a rental of so much per net registered ton. The gross tonnage is frequently the basis in time charters of passenger vessels. During the World War the Shipping Board requisitioned passenger vessels and paid for them from $9 to $11.50, per gross registered ton per month, depending upon their speed. Since tonnage taxes and port charges form a considerable portion of a vessel's expenses, it may be imagined that every owner is anxious to have his builder reduce net tonnage to the lowest possible figure. This naturally has its effect upon shipbuilding design.

Cargo Tonnage

Cargo tonnage may be measured in terms of either weight or volume. The weight ton is a long ton of 2240 pounds avoirdupois, a short ton of 2000 pounds or a metric ton of 2204.63 pounds, the first being more important in the ocean carrying trade of the United States and the short ton only occasionally used. The measurement ton indicates 40 cubic feet of space and is thus a measure of volume and not of weight, corresponding in this respect to the vessel measurement ton. The origin of the measurement ton of freight has been variously deduced. One explanation is that this is approximately the amount of space occupied by one of the "tuns" of wine which formerly played an im-

portant part in the English trade with the Continent. Another is that it originated in the French "tonneau de mer," which by French measurement approximated 42 cubic feet but by English measurement 51 cubic feet. A third explanation is that this was roughly the amount of space occupied by a ton of grain, an article intermediate between the heavy and light varieties of cargo.

It has been previously explained that cargo naturally divides itself into two classes, weight and measurement. A weight cargo is one which occupies so little space in proportion to its weight that the amount carried by the vessel is only limited by its displacement or deep load line. A measurement cargo is one so light and bulky that the amount carried is limited by the vessel's internal volume. Naturally, to carry measurement cargo on a weight basis would be a losing proposition, as would weight cargo on a space basis and, therefore, in ocean tariffs it is common to charge so much per ton, weight, or measurement, at the ship's option, or to specify a charge per measurement ton in some cases and per weight ton in others. Freight rates are often quoted on other units applying these principles of space and weight, and these same results are incorporated in classified freight lists.[2]

As a result of the indiscriminate use of these two units, figures of cargo tonnage are of little use for statistical purposes unless analyzed. Another result of this same distinction in cargo is that while a simple relation exists between vessel displacement and cargo tonnage in weight, and to a lesser degree between register tonnage and space tonnage of cargo, neither the space nor displacement of a vessel alone can give an accurate idea of its cargo capacity. The most profitable loading is usually one which combines weight and measurement cargo in ideal proportions, these proportions being determined by the character of the cargo.

The gross tonnage of a vessel is sometimes compared with the dead weight. Inasmuch as the freeboard assigned in Great Britain is largely a result of the deck erections, as previously described, the under-deck tonnage is inapplicable. The following comparison was made some years ago of (A) well-decked vessels with short well and gross tonnage varying from 1500 to 2500 tons, (B) an ordinary well-decker, with long well,

[2] See G. G. Huebner, *Ocean Steamship Traffic Management*, D. Appleton & Co., New York, 1920, 229–235.

gross tonnages from 1100 to 2300, (C) well-deckers with wells filled in by forecastle and bridge being joined, gross tonnages from 2100 to 2500 and very similar to a spar-decked vessel, (D) spar-deckers, gross tonnage from 1500 to 2700 and (E) three-deck type, with two decks laid, gross tonnages from 2500 to 3500.

Type of ship		Dead-weight capacity divided by	
		Weight of hull, Machinery and Equipment	Gross Register Tonnage
A. (15 examples)....	max.	2.40	1.54
	min.	1.99	1.37
	mean	2.21	1.47
B. (4 examples).....	max.	2.28	1.51
	min.	1.70	1.30
	mean	1.97	1.39
C. (5 examples).....	max.	2.48	1.53
	min.	2.16	1.46
	mean	2.30	1.15
D. (5 examples).....	max.	2.59	1.60
	min.	1.97	1.50
	mean	2.36	1.55
E. (4 examples).....	max.	2.32	1.66
	min.	2.00	1.53
	mean	2.17	1.60
Mean of the five types		2.20	1.50

Apparently the spar-decked vessels carry the largest dead-weight cargoes in proportion to the weight of the vessel, while three-deckers carry the largest dead-weight cargoes in relation to register tonnage. The tonnage as given above is under British rules. The variations in the ratios of dead-weight capacity to register tonnage are surprisingly small, the average ratio being 1.5 to 1.

Various means were at one time employed to estimate cargo space tonnage from the register tonnage. One rule, for example, was to multiply the register tonnage under the tonnage deck by 1⅞. It was simply estimated that out of every 100 cubic feet of vessel capacity, 25 cubic feet were rendered useless by breakage of stowage by beams, knees, sleepers, and the necessary carriage of provisions, water, and stores, leaving 75 cubic feet available for cargo. Dividing this by 40 cubic feet, a cargo space ton, gave 1⅞. At present this is considerably exceeded, since with

the improvement in shipbuilding methods the stowage space is less broken up and the space for water, is reduced. But the engine space should be deducted, and this bears no constant relation to the size of the vessel, as explained later. At present the builder furnishes the owner tables indicating capacities. Variations in the methods of measurement employed by the builder, some making deductions for broken space, render these

HOLD CAPACITIES
(including hatches)

Location	Gross cubic feet	Net cubic feet
Hold No. 1	51,360	48,300
Hold No. 2	57,460	54,550
Hold No. 3	23,730	22,260
Hold No. 4	48,390	45,400
Hold No. 5	34,550	31,700
'Tween-decks No. 1	26,426	23,784
'Tween-decks No. 2	31,105	29,808
'Tween-decks No. 3	13,978	12,589
'Tween-decks No. 4	29,780	26,802
'Tween-decks No. 5	28,020	25,217
Storage	5,000	4,500
Bridge	27,864	23,433
Poop	9,765	8,300
Total	387,428	356,643

Note.— Gross capacity calculated to top of beam, outer edge of frames and top of tank ceiling: net capacity calculated to bottom of beams, inner edge of cargo battens and top of tank ceiling.

WATER-BALLAST CAPACITIES

Tank	Capacity in tons
No. 1 tank	109
No. 2 tank	198
No. 3 tank	225
No. 4 tank	75
No. 5 tank	
No. 6 tank	209
No. 7 tank	91
Fore peak tank	99
After peak tank	65
Deep tank	678
Total	1,749
No. 5 tank (feed water)	83
Total	1,832

results to some extent uncertain. The accompanying illustration for a cargo vessel of 5125 gross tons shows the information customarily furnished.

Coal Bunker Capacities

Location	Tons	Cubic feet
No. 3 hold	552	23,730
Bridge	648	27,864
Midship 'tween-decks	255	10,965
'Tween-decks under bridge	325	13,978
Pocket bunkers	12	516
Total	1,792	77,053

For purposes of stowage, books have been compiled giving the results of measurement and experience, as, for example, Stevens. Here may be found tables giving comparisons of space and weight for different commodities in various conditions and forms of shipment. The following is an illustration of such information for grain:

	Loosely filled		Closely filled and packed	
	Pounds per bushel	Cubic feet per ton	Pounds per bushel	Cubic feet per ton
Wheat				
Red Winter	62.9	45.7	68.0	42.3
Bombay	62.9	45.7	68.0	42.3
California	62.9	45.7	68.0	42.3
Walla Walla	59.0	48.7	64.8	44.3
Bessarabia	62.9	45.7	68.0	42.3
Peas, American	64.2	44.8	69.3	41.5
Maize				
White American	55.8	51.5	60.3	47.7
Mixed	56.5	50.9	60.3	47.7
Oats, Russian	35.9	80.0	42.4	68.0
Beans, Egyptian	59.0	48.7	64.2	44.8
Barley, English	50.1	57.4	56.5	50.9

CHAPTER IX

DISPLACEMENT AND DEAD-WEIGHT TONNAGE

Displacement

A ship floating in still water displaces a certain volume of water, greater or less, depending upon its weight. For if a bowl is filled to the brim with water and a block of cork placed therein, some water, but very little, will overflow. If a block of oak is placed afloat, however, considerably more of the fluid will overflow. If the overflowing water is caught and weighed it will be found that its weight is exactly equal to the weight of the floating body. This is an elementary law of physics and explains how the term displacement comes to be applied to merchant vessels. The quantity of water displaced is the "volume of displacement" and the weight of water displaced is termed the "weight of displacement." The former is expressed in cubic feet or cubic meters and the latter in tons of 2240 pounds or in kilograms. When we speak of the displacement of a vessel we mean the weight of the vessel in tons of 2240 pounds as ascertained by weighing the quantity of water displaced by the vessel when afloat.

Displacement is not in any way connected with form or dimensions. Vessels of equal weight will have equal displacements, though their forms vary greatly, and the weight of displacement of a vessel is as constant as its own weight. When a vessel passes from fresh to salt water the volume of displacement must decrease because of the increasing density of the water; but the weight of displacement remains the same, the smaller volume of water being compensated for by the greater weight per unit of volume. To put it in another way, the weight of displacement remains the same but the displacement volume and draft change. Therefore, we find both fresh-water and salt-water load lines marked on vessels.

Displacement and Buoyancy.— Unless the weight of the object in question is greater than the weight of the water dis-

placed it continues to float. The weight of the water displaced marks the limit of floating power and measures the "buoyancy" of the object. The terms buoyancy and displacement may therefore be used interchangeably.

Forms of Displacement.—Displacement is defined as the weight of water displaced by a floating vessel. But the term "vessel" is an indefinite one, for it may refer to the hull before the machinery has been introduced; the vessel complete but without any fuel or cargo on board; the vessel fully coaled but partly loaded with cargo; or the vessel fully loaded and ready for sea. These various conditions give rise to customary and well-understood forms of displacement. "Light displacement" is the weight of the powered vessel with crew and supplies on board, but without fuel, cargo, or passengers. "Loaded displacement" is the weight of the vessel with crew, supplies, and fuel on board and fully loaded. Since we are now speaking in terms of weight we mean by "fully loaded" the maximum weight of cargo and not necessarily the maximum volume of cargo. Thus the vessel may be weighted down to the highest point consistent with safety and yet if filled with articles of great density considerable space will remain unoccupied. The volume and density of cargo will both influence the displacement of the vessel, and since these vary from time to time the term "actual displacement" originates, indicating the weight of the vessel when loaded to any given draft. Light displacement and loaded displacement are therefore constants for a given vessel while actual displacement is a variable quantity dependent upon cargo carried.[1]

It is apparent that the weight of cargo might also be measured by its displacement and this, in fact, is actually done indirectly

[1] Displacement is an important measure for war vessels. "Full displacement" in this connection corresponds to loaded displacement for merchant vessels. Light displacement means the displacement of a war vessel with complete battery and outfit, but without officers, crew and their effects, ammunition and stores, water for drinking and machinery, fuel and reserve feed water. The definition differs in various countries. Normal displacement is the weight of a warship completely equipped with a full complement of officers and crew, their effects, full equipment, armament and machinery, and two-thirds of its full allowance of stores, coal, fuel oil, and water. There is no international uniformity in the definition of this displacement. Actual displacement is the weght of the vessel at a given time. The above are American definitions. For a discussion of war vessel displacement see E. R. Johnson's "Report on the Measurement of Vessels for the Panama Canal," Washington, 1913.

through the extra displacement given to the vessel by cargo on board.

Calculation of Displacement.— The displacement of the vessel or weight of water displaced may be measured in various ways:

1. One method would be to collect the water displaced and weigh it. This, however, is tedious, impractical and would not enable one to know the displacement until the vessel was afloat.

2. Since we know that a cubic foot of sea water weighs close to 64 pounds or $\frac{1}{35}$ of a ton avoirdupois, we can ascertain the displacement weight from the displacement volume. The volume of water displaced will be equal to the under-water volume of the vessel, or, in other words, the portion of the hull below the water line. To find the volume and consequently the weight of water displaced it is only necessary to find the volume of the vessel below the water line. This is the accurate method adopted by the naval architect, the necessary dimensions being ascertainable from the drawings. As the Moorsom method and Simpson's rule are applied to find the total volume of a vessel (see page 182) so they can be applied to find the under-water volume. Dividing the immersed portion of the vessel into sections by transverse vertical planes erected at equal intervals (see illustration, page 183), the areas of these transverse vertical sections are measured by Simpson's rule as described in a later chapter and by applying multipliers to these areas the under-water volume is accurately obtained.

3. It is convenient, however, to have some briefer method of approximating the displacement, both to save time and to give approximate results when the necessary measurements for the accurate system are lacking. If the under-water portion of a vessel were in the form of a block with parallel sides its volume and the volume of water displaced by it could be accurately found by the product of the length, breadth, and depth. This divided by 35 (since 35 cubic feet of sea water weigh one ton) would give the displacement tonnage. The formula would be

$$\frac{L \times B \times D}{35}$$

But a vessel is rounded off or "fined" off toward the keel and toward the ends so that its volume is considerably less than the

volume of the corresponding block. We have therefore a ratio

$$\frac{\text{Volume of vessel under water}}{\text{Volume of block with similar dimensions}}$$

which will yield a result lower than 1, that is, in the form of a percentage. The greater the rounding-off and the "finer" the lines of the ship the smaller this percentage will be, for it expresses the relation between the volume of the vessel and the volume of the block, being therefore known as the "block coefficient." The block coefficient may be selected by considering the qualities of the vessel, particularly the speed. The following are a few examples given by Walton:

.8 would be a very full vessel.
.7 to .75, an average cargo steamer.
.65, a moderately fine cargo steamer.
.6, a fine steamer, such as used for passenger service.
.5, an exceedingly fine steamer, but an average for steam yachts.
.5 to .4, in fine yachts.

Thus for a vessel 410 feet long, 56 feet broad, and with 30 feet draft, assuming a coefficient of .81 the displacement would be

$$\frac{410 \times 56 \times 30 \times .81}{35}, \text{ or } 15{,}930 \text{ tons}$$

Or, given the length, breadth, mean draft, and displacement at that draft, it is possible to estimate the block coefficient. The formula becomes

$$\frac{35 \times 15{,}930}{410 \times 56 \times 30}, \text{ or } .81$$

The volume of the under-water portion of the hypothetical block above referred to will be recognized as the "block displacement" referred to in Chapter VIII as a possible basis for assessing tolls and charges.

4. Since the length, breadth, and coefficient of fineness are constants for a given vessel and the displacement varies with the depth it is convenient to figure at once the displacements at various depths and make a record of the same, so that an officer of the

vessel knowing the draft can ascertain from the record the displacement, without calculation. The displacements at various drafts may be ascertained by calculations based on the coefficient of fineness or preferably by the Moorsom system, and the results presented in graphic form (see Figure 55).

On this diagram a vertical scale of displacement is plotted across the top. The curve is composed of the points of inter-

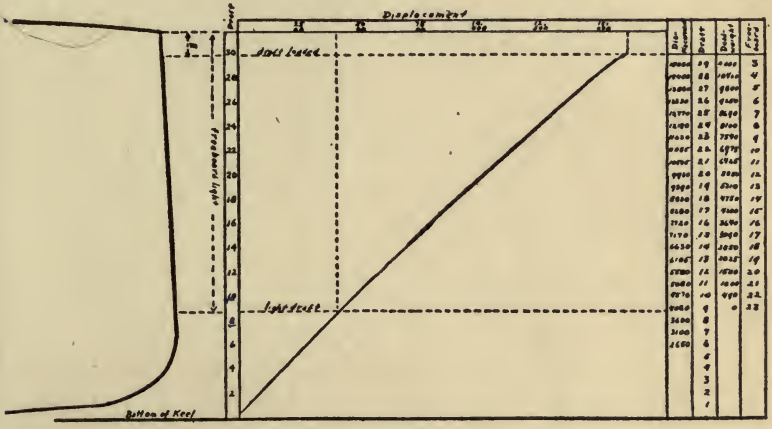


FIG. 55.— DISPLACEMENT SCALE

section of various drafts and displacements, as figured by the marine architect. At a draft of 9 feet if we draw a line parallel to the base of the diagram we find that it intersects the curve at approximately the point 4000 on the displacement scale above. Similarly, a horizontal line drawn through the 30-foot draft intersects the curve at a displacement of 15,930. It is possible by inspection of this diagram to obtain fairly accurately the displacement at any given draft or the draft at any given displacement. At the right of the diagram, however, is a so-called vertical displacement scale, combined with a dead weight and freeboard table. Column 2 indicates various drafts and column 1 indicates the displacements at these drafts. It is possible to calculate from this diagram, also, the number of tons required to be loaded on or unloaded from a vessel in order to increase or decrease the draft by 1 inch, but the diagram is not very conveniently arranged for the purpose A more convenient form is the immersion curve.

5. The immersion curve is a curve showing the displacement per inch immersion or emersion at various drafts. This is not as constant as it would be for a box-shaped object, where the number of tons per inch is the same at any draft. As the vessel sinks in

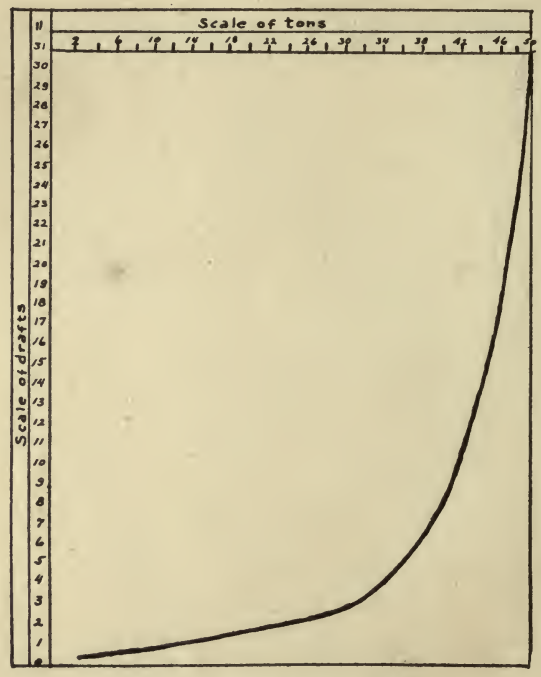


FIG. 56.— IMMERSION CURVE

the water it requires more and more tons to immerse it another inch (see Figure 56).

DEAD-WEIGHT TONNAGE

Dead-weight tonnage is the displacement of the total amount of fuel, passengers, and cargo that the vessel can carry. The dead-weight tonnage therefore measures the capability or carrying power of the vessel for the transportation of weight cargo. The capability for light cargo is better measured, of course, by volume. Dead weight is carrying power, over and above the actual weight of the vessel and equipment. Dead weight is used in two senses:

1. Maximum dead weight, or the carrying power of the vessel at the maximum draft. This represents the largest amount of cargo which can be safely carried. It is, therefore, the difference between the "light displacement" of the vessel and the "loaded displacement."

2. Actual dead weight, or the carrying power of the vessel at a given draft. This represents the amount of cargo which is being carried at a given time. It is, therefore, the difference between the "light displacement" of the vessel and the "actual displacement."

Measurement of Dead Weight.— 1. By the weight of water displaced. This is done indirectly by taking the difference between the vessel displacements, light and loaded or light and actual.

2. By the difference in displacements as described above.

3. Dead-weight scale. It is customary to figure out in advance the dead-weight capacity at various drafts and to combine this information in the form of a dead-weight scale with the displacement curve (see columns 2 and 3, Figure 55). If given separately it has the form of the accompanying diagram.

4. The uses of these diagrams and tables in connection with dead-weight tonnage may be illustrated as follows:

Suppose the vessel previously used for illustration is ready to enter a river port. Her displacement is 15,080 tons and she is drawing 29 feet (in sea water). The depth at the dock in the river is 31 feet. Can she enter? This depends upon how much increase in draft will be caused by the change from sea water to fresh water. Since the weight of the water displaced must equal the weight of the vessel and since sea water weighs 64 pounds to the cubic foot and fresh water only 63 pounds, it is evident that there will be some increase in draft. From the immersion curve it can be ascertained that the number of tons per inch immersion in salt water at this draft is 70.8. It will be sixty-three-sixty-fourths of this or 69.69 in fresh water. The displacement in sea water was 15,080 tons and the displacement in river water will be one-sixty-fourth more, or 235.6 tons more. The change in draft will be 235.6 divided by 69.69, or 3.38 inches. The draft in fresh water will be 29 feet 3.38 inches. The same idea is useful in ascertaining that the vessel when loaded at the dock shall not exceed her maximum draft when at sea. Sup-

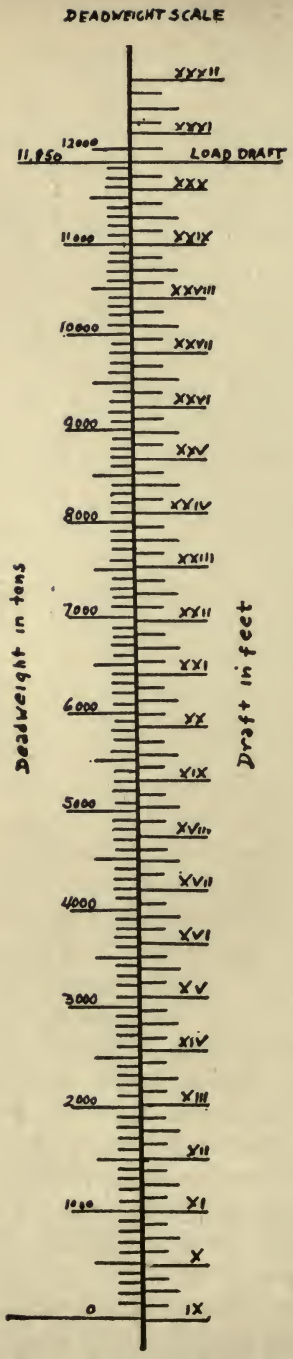


FIG. 57.— DEADWEIGHT SCALE

pose again that a vessel discharges cargo, the weight of which is not known. If the tons per inch at the vessel's draft was ascertained from the immersion curve to be 60 and the draft has decreased from 29 feet to 28½ feet, the weight of the cargo discharged must be approximately six times 60, or 360.

Relation between Displacement and Dead Weight.— Using other terms, this might be stated as the relation between ship displacement and cargo displacement. This is a very important relation in connection with the safety of the vessel and by reason of laws designed to make ships seaworthy and safe is fast becoming a legal question not inferior to tonnage in international importance.

Nature of the Relation.— The portion of the vessel under water determines the displacement or buoyancy of the vessel. But it has a floating power beyond this or a reserve buoyancy which is determined by the part which is not immersed but may be made water-tight, enclosed by the upper deck and by the bridge, forecastle, and poop. As stated by White, "The sum of the two, in short, expresses the total 'floating power' of the vessel and the ratio of the part which is in reserve to that utilized is a matter requiring the most careful attention." This ratio might be called, in one sense, a "factor of safety." Like the surplus over fixed charges of a corporation, it enables the vessel to pull through difficulties. This ratio may be more or less accurately translated into the distance between the water line and the height of the upper deck, crudely speaking, the portion of the hull out of water, and this distance on the side of the vessel when it is fully loaded is called the minimum "freeboard." The water line on the vessel when fully loaded is called the "load line."

The "freeboard," accurately defined, is the height of the side of the ship above the water line, at the middle of the length, measured from the top of the deck at the side or, in cases where a waterway is fitted, from the curved line of the top of the deck continued through to the side, (see Figure 55). The freeboard will naturally vary with the type and construction of the vessel. A submarine, for example, designed to operate partially or wholly submerged, has no freeboard, while a passenger vessel not designed to carry heavy cargo and the upper portion of which is lightly constructed will have considerable freeboard. Fixing the minimum freeboard determines the maximum loading

capacity, which the owner usually desires to have as great as possible.

Rules for Freeboard

In some types of vessels the freeboard is measured to the main deck, the superstructures being light, but we will temporarily consider the freeboard as measured to the upper deck.

1. **Old Rules.**— Fixing the minimum freeboard determines the maximum loading capacity. Originally no government supervision was exercised over this whatever, so that greedy vessel-owners were free, if they so desired, to risk their property and the lives of sailors in grossly overloaded vessels. Even under these conditions there existed some formulas for the benefit of those who desired to use them. The oldest English rules were based upon the depth of the vessel's hold, Lloyd's rule providing a freeboard of from 2 to 3 inches for every foot of depth in the hold. This rule took no account of differences in the form of vessels or of differences in size, both of which affected the working of the rule. Liverpool underwriters directed surveyors to make allowance for form and strength when assigning freeboards and provided graded scales ranging from 2¼ inches to 4 inches per foot depth of hold.

2. **Institution of Naval Architects' Rules, 1867.**— This body devised a set of rules with freeboard dependent upon beam. The necessary freeboard was calculated at $\frac{1}{8}$ of the beam plus $\frac{1}{32}$ of the beam for every beam in the length of the ship above 5 beams. Thus a vessel with 32 feet beam and 224 feet long (7 beams in the length) would have a freeboard

$$\frac{1}{8} \times 32 + \frac{2}{32} \times 32, \text{ or } 6$$

Lloyd's rule ignored the ratio of length and breadth; this rule omits any consideration of the depth of the vessel. Deep, narrow vessels which would require exceptionally large freeboard because of bad proportions would receive a smaller freeboard than a vessel of equal length but better proportions. In present-day vessels the freeboard requirement arrived at by the use of a rule of this character would in most instances be excessive. This rule never attained any general use.

Load Line Legislation

As a result of losses of vessels at sea alleged to be due to overloading, many investigations were made between 1870 and 1890 regarding the safety of vessels at sea. Plimsoll considered that property was sacrificed and sailors murdered through lack of load line legislation.

1. **Commission of 1874.**— This commission reported that it was impossible to lay down any general rules on the subject of freeboard.

2. **Act of 1876.**— By act of Parliament in 1875, on the side of vessels in the foreign trade owners were required to have painted a mark now referred to as the Plimsoll mark, which indicated the limit of loading. This provision was extended by the Act of 1876 to apply to all British vessels of over 80 tons. Official surveyors had authority to detain vessels considered as overloaded, though owners might claim damages if unjustly detained. These marks, it will be noticed, were placed at the discretion of the owners and really only served as a guide and protection to the master of the vessel. As was natural in the absence of any satisfactory criterion, many disputes arose and the act did not accomplish its purpose, except in a limited way. Its principal function was to pave the way for further legislation.

3. **Lloyd's Tables, 1882.**— A committee of Lloyd's Register of Shipping had for ten years been compiling data relative to the loading of vessels and freeboard, and the results of these investigations were embodied in the tables of freeboard issued in 1882. These took into account the structural design and form of the hull and the various practices of loading, and, when in 1883 the Board of Trade appointed a committee to investigate the possibility of adopting freeboard tables, this committee urged the adoption of the Lloyd's Tables with slight modifications. The recommendation was followed by the Board of Trade. As a result a shipowner who obtained a Lloyd's certificate and had his vessel properly marked was free from the possibility of detention for overloading, and by 1890 over 2000 vessels had made voluntary application to Lloyd's for this purpose.

4. **Act of 1890.**— These tables were embodied in the Merchant Shipping Act of 1890 and made applicable to all British merchant vessels. In 1906 it was decided that the freeboard required for

vessels with substantial deck erections were excessive and the tables were revised in this respect, the reduction varying from ½ inch to 12 inches, depending upon the type of vessel. In 1913 a further investigation was made by the Board of Trade and it was decided that the freeboard tables of 1906 were substantially correct. The principal work of this committee was to revise the treatment accorded special types of vessels, which had received preferential treatment. At the present time the owner may secure a load line marking from a Board of Trade inspection or inspection by Lloyd's, Bureau Veritas, or British Corporation, the latter three classification societies having been recognized for this purpose.

Principles of Load Line Regulation

It is possible to give a brief outline of the factors which are of principal importance in the fixing of the maximum load line, as illustrated by the law of Great Britain. As preliminary thereto it might be stated that there are two elements connected with the fixing of freeboard, (1) the avoidance of a loading so heavily as to strain the vessel, and (2) the maintenance of weatherly qualities. The latter object is more difficult to attain than the former, because of the many varieties of vessels and the diverse conditions under which they sail. Its accomplishment involves sufficient reserve buoyancy, decks not readily swept by waves, and good wave-riding qualities. The principal factors in the British tables are:

1. **Strength.**— The criterion of strength is a first-class vessel according to Lloyd's rules of 1885. The calculated stress per square inch on the material of the hull amidships must not exceed the calculated stress for a full-scantling vessel of similar form and proportions when fully loaded. Vessels may have any form of construction but must meet this test. A table is constructed in which various depths of ships are listed and below each depth is given the standard length for such depth and the number of inches of freeboard required for vessels having this depth and various coefficients of fineness. An illustration of such a table is given below.

Adopting as an illustration a flush-decked vessel, 300 feet long, 38 feet broad and 21 feet molded depth, with a coefficient

Depth in feet.....		20.0	20.5	21.0	21.5	22.0	23.0
Length in feet.....		240	246	252	258	264	270
		in.					
Coefficient of fineness	.66	42.6	44.2	45.9	47.6	49.3	51.1
	.68	43.2	44.8	46.6	48.3	50.0	51.8
	.70	43.9	45.5	47.3	49.0	50.7	52.6
	.72	44.5	46.2	48.0	49.7	51.4	53.3
	.74	45.1	46.8	48.6	50.4	52.1	54.0
	.76	45.8	47.5	49.3	51.1	52.8	54.7
	.78	46.4	48.2	50.0	51.8	53.5	55.4
	.80	47.1	48.9	50.7	52.5	54.3	56.2

of fineness 80 per cent we find from the table that the freeboard required would be about 51 inches. A vessel which was not of standard strength would have the alternatives of increasing the structural strength or having the tabular freeboard increased until by a corresponding reduction of the load on the hull girder the stress would be brought within the limits of a standard ship. Naturally, therefore, a spar-decked or awning-decked vessel, which is of lighter construction than a full-scantling vessel, would have a greater freeboard than the latter. This is taken care of by separately providing for these types of vessels in the tables. No reduction in freeboard is given, however, for a vessel of greater structural strength than the standard, because, as previously stated, weatherly qualities must be considered and if strength alone were a criterion it would be possible to build a vessel for which no freeboard was necessary.

2. Reserve Buoyancy.— Reserve buoyancy enables the vessel to rise smartly when among waves and therefore is necessary in some degree to all seagoing merchant vessels. Otherwise waves would continually sweep the decks, with the possibility of water entering the ship. The reserve buoyancy is principally dependent upon (*a*) the sheer and (*b*) superstructures. If the ship has sufficient sheer the ends are more buoyant and the stem and stern less likely to be swamped by oncoming and following waves. A flush-decked vessel, without sheer, and loaded to the gunwales would have no reserve buoyancy, would not lift with the waves, would float nearly submerged if the upper deck was water-tight, and would be continually washed by the waves. The wave-riding qualities are not measured solely by the absolute volume of reserve

buoyancy but by the proportion which it bears to the vessel's displacement, because if not of sufficient proportion, while the vessel would rise it would not rise quickly enough. Suppose, therefore, that the vessel used above as an illustration has a sheer forward of 8 feet and a sheer aft of 3 feet or a mean sheer of 66 inches. According to the rules, the mean sheer for a standard vessel is $\frac{1}{10}$ of the length in feet plus 10. For a vessel 300 feet long the sheer would be $\frac{1}{10}$ of 300 plus 10 or 40 inches. This vessel, however, has a sheer of 66 inches or a surplus of 26 inches. Only .5 of the standard is allowed as excess, however, so that the excess is considered as 20 inches. One-fourth of this excess, or 5 inches, is allowed by the rules as a deduction from the freeboard, thus reducing the freeboard from 51 inches to 46 inches.

3. **Form.**— It should be noted that the freeboard for a large vessel must be greater in proportion to depth than for a small vessel inasmuch as several waves may be acting on the length at the same time. Thus the top of a small plank may remain perfectly dry, rising with each wave, while the top of a long plank will be wetted because each portion of the length is submerged as a small wave passes. The length of the hull is, therefore, an important factor in freeboard. The standard relation of length to depth is 12 to 1. The vessel used as an illustration has a length of 300 feet and a depth of 21 feet. Since its length is more than 12 times the depth an allowance for this must be made in freeboard. For each 10 feet of additional length a correction of 1.2 feet must be added to the freeboard (this correction being a fraction of the length plus a constant, ascertained from the rules). The length of this vessel exceeds the standard length for the given depth by 48 feet. The correction would, therefore, be $\frac{48}{10} \times 1.2$, or $5\frac{3}{4}$ inches, which added to the freeboard already calculated (46 inches) would give 51.75 inches as the winter freeboard. From this is deducted so many inches per foot of draft to arrive at the summer freeboard.

In connection with form it will also be noticed that by means of the coefficients of fineness in the table on page 169 a greater freeboard is required for a full than a fine vessel. Other things being equal, the full vessel is less lively than the vessel with finer lines.

4. Deck Erections.— We have previously stated that deck erections are an important factor in reserve buoyancy. The forecastle and poop, for example, serve the same purpose as sheer in making the ends of the vessel lively. The forecastle is the most important deck erection for its length, because it adds buoyancy where it is most effective, raising the bow to meet the waves and minimizing the effect of head seas. A poop performs the same function at the stern. The bridge raises the working platform out of water and covers the machinery openings. Deck erections, in order of value from freeboard standpoint, are listed as follows:

a. Continuous end-to-end erection forming awning deck of an awning-decked vessel.
b. Erection in the form of a shelter deck.
c. Well-decked vessel or forecastle, bridge and poop, varying according to completeness and continuousness.

The length and completeness of closure evidently determine the effectiveness of the erections. The shelter deck with tonnage openings can never be better than the awning deck nor can a forecastle, bridge and poop covering three-fourths of the length be superior to a shelter deck, using this term in the sense now employed. Suppose, therefore, that the vessel previously used for illustration has a poop 50 feet long, a bridge 60 feet long, and a forecastle 25 feet long. The combined erections cover 45 per cent of its length. The tables give the allowance to be made for a complete superstructure (say 32 inches), and for one covering only 45 per cent of the length allow one-fourth of the deduction for a complete superstructure. The allowance in this case would, therefore, be, say, 8 inches. The flush-decked vessel's freeboard would consequently be reduced by the deck erections from 51.75 inches to 43.75 inches.

5. Side Openings.— There may be exceptions to the above rules in the case of vessels whose side openings prevent the assignment of a load line as high as that calculated by the tables.

6. Variance of Load Line.— The load line must necessarily vary with the season of the year and the nature of the voyage. Accordingly, we find the following freeboards marked:

a. Fresh water freeboard is the minimum freeboard permitted in summer when vessels are loaded in fresh water. The difference

between the summer fresh water freeboard and the summer salt water freeboard is the allowance to be made for loading in fresh water at other seasons of the year.

b. Indian summer freeboard is the minimum freeboard permitted in salt water for voyages in the Indian Seas, between the limits of Suez and Singapore, during the fine season.

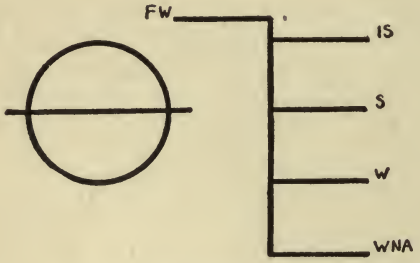


FIG. 58.— FREEBOARD MARKS

c. North Atlantic winter freeboard is the minimum freeboard permitted in salt water for voyages from, or to, European or Mediterranean ports to, or from, North American ports situated north of Cape Hatteras, between the months of October and March, inclusive.

d. Winter freeboard is the minimum freeboard permitted in salt water for voyages from European or Mediterranean ports between the months of October and March, inclusive, and for voyages in other parts of the world during the recognized winter months, subject to the exception provided in (*c*) above.

e. Summer freeboard is the minimum freeboard permitted in salt water for voyages from European or Mediterranean ports, between the months of April and September, inclusive, and for voyages in other parts of the world during the recognized summer months, subject to the exception provided for in (*b*) above.

PROPOSED REVISION OF 1916

A committee appointed by the Board of Trade in 1913 reported to Parliament in 1916 that the freeboards assigned by the rules were apparently satisfactory so far as safety was concerned and had not contributed to losses at sea. They recommended a revision of the rules, however, to eliminate preferential treatment

of types of vessels not satisfactorily covered by the old rules. The principal changes recommended were the following:

1. The existing rules tabulate the winter freeboards while the proposed rules tabulate the summer freeboards with additions for winter.

2. Existing rules classify steamers according to the extent and disposition of their superstructures — to some extent an arbitrary classification with some classes merging into others — and, as the deduction is different in each class, this results in some anomalies. The proposed rules introduce a "type factor," separate factors being assigned to vessels of different types and the allowance for superstructures being the result of the formula $F \times R \times D$, F being the type factor, R the ratio of superstructure length to total length, and D the reduction given for complete superstructures.

3. In the proposed rules two standards for sheer are proposed, one for vessels with forecastles and a higher standard for those without. In the existing rules an allowance is made for an excess of sheer in flush-decked vessels but no such reduction is allowed in the proposed rules.

4. The correction for the ratio of length to depth has been embodied in the proposed rules as a function of the length, the increase or decrease in freeboard being

$$(.0003\ L + .05)\ (L - 12D)$$

L being the length and D the freeboard depth of the vessel in feet. The standard ratio is retained as 12 to 1, except that when the ratio of length to depth exceeds 15, the freeboard shall be computed as if the ratio were 15.

5. Holms, who was a member of the committee, expresses his opinion as to the effect of the changes on existing freeboards as follows:

> The freeboards given by the rules formulated by this committee vary very little, in the majority of vessels, from those given under the old rules; any difference there may be being due principally to the avoidance of special treatment of certain types of vessels, and to a reduction in the allowance made for superstructures the means of closing the openings in the terminal bulkheads of which are not up to a certain standard. Compared with the old rules, the new are easy to apply and are simple and accurate.

United States Legislation

An act of 1891 provided that "the owner, agent, or master of every inspected seagoing steam or sail vessel shall indicate the draft of water at which he shall deem his vessel safe to be loaded for the trade she is engaged in, which limit as indicated shall be stated in the vessel's certificate of inspection, and it shall be unlawful for such vessel to be loaded deeper than stated in said certificate." As stated by the Commissioner of Navigation, the effect of this was to place more scrupulous owners at a commercial disadvantage, and the law was repealed in 1897. At the present time no load line legislation exists. In 1916 a conference was held between the Secretary of Commerce, shipbuilders, shipowners, and representatives of classification societies, and the matter was referred to a committee for recommendations. A bill is now pending in Congress requiring load line regulation, providing for a load line to be marked on vessels as the Secretary of Commerce may suggest, and for the recognition of substantially similar foreign laws. As was the case with tonnage measurement, foreign nations followed the example of Great Britain, and Germany, France, Holland, and other maritime nations passed similar laws. Numerous experts have testified to the necessity of an established load line but vessel owners have always feared it would operate prejudicially to certain trades or types of carriers. The most effective method of dealing with this subject would be through an international conference which would make common regulations for all nations. Each nation is, of course, reluctant to pass load line laws which will hamper its merchant marine in competition with foreign vessels. The International Conference on Safety at Sea which met during the World War considered this question, but the matter was deferred until the close of hostilities. The subject will be a prominent one at the next conference.

References

1. Johnson, E. R.: *Report on Panama Canal Traffic and Tolls.* Washington, 1913. Chap. III. (A brief discussion of the nature of displacement and dead-weight tonnage and extended consideration of its desirability as a basis for canal tolls.)

2. HOLMS, A. C.: *Practical Shipbuilding.* Longmans, Green & Co., London and New York, 1916. Chap. VII. (Extensive discussion of the factors influencing the regulation of load lines, history of English legislation, description of the recommendations of the Committee of 1916.)
3. WALTON, THOMAS: *Know Your Own Ship.* Griffin & Co., London, 1917. Chap. I. (A good discussion of displacement and dead-weight tonnage and their calculation.) Chap IX. (A good discussion of present British regulation of the load line.)
4. WHITE, W. H.: *Manual of Naval Architecture.* Murray, London, 1894. Chap. I. (Good description of displacement tonnage and of British load line legislation up to 1890.)
5. "Report of Board of Trade Committee to Parliament, Great Britain, 1916." In "Report of Commissioners, etc.," 1916. Vol. X, Cd. 8204. (Brief history of British laws and proposed revised rules and tables of freeboard.)
6. "Reports of Commissioner of Navigation, United States, 1915, 1916, 1919." (Notes of progress in load line legislation in United States.)
7. Conference on Establishment of Load Line Regulations, Dept. of Commerce and Labor, United States. Washington, 1916.

CHAPTER X

GROSS TONNAGE

Definition

Gross tonnage is an attempt to express, in units of 100 cubic feet, the internal cubical capacity of a vessel, in other words, its volume. If a vessel were a parallelopipedon (a six-sided object with opposite sides parallel and equal to each other) the volume would be measured by the product of the length, breadth, and depth, and would be expressed in tons of 100 cubic feet by dividing by 100. It is evident that the volume of a vessel will be dependent upon these three factors, but being rounded off toward the keel and sharpened at the ends its sides are not parallel and consequently it has a volume considerably less than the product of its greatest length, breadth, and depth. In the early rules attempts were made to estimate the space in a vessel by the product of these three factors modified by some divisor intended to deduct a fraction of the result obtained to allow for such rounding off. Thus, in a book published in 1711 "two good old rules" are quoted, one being

$$\frac{L \text{ (length)} \times B \text{ (breadth)} \times D \text{ (depth)}}{95} = \text{gross tonnage}$$

Similarly the first tonnage law in England (1694) prescribed the rule

$$\frac{L \times B \times D}{94} = \text{gross tonnage}$$

Such rules could apply equitably to all vessels only if there were a uniform degree of rounding off toward the keel, stem, and stern, which was decreasingly true as ships became more varied and intricate in design. If the factor of 94 was correct for the "full" ship it was palpably unjust to the vessel with finer lines

or vice versa. Furthermore, the rule is so simple that as soon as incentive appeared in the form of duties based on registered tonnage it was easy for enterprising shipowners and builders to construct vessels designed to evade the rule. For example, when it was assumed that the depth of a vessel bore a fixed relation to its breadth of 1 to 2 and the rule was modified in England (1720) to

$$\frac{L \times B \times \frac{1}{2} B}{94} = \text{gross tonnage},$$

vessel depths grew surprisingly in comparison with breadths. Ships became deep and unseaworthy boxes, because this increased the carrying capacity without affecting the legal tonnage. Fullness of lines had a similar effect.

The definition shows gross tonnage to be a measure of the volume of a vessel. But since it is not a mere exercise in mensuration and has a purpose, this definition must be somewhat modified to bring it in accord with the purpose of approximately stating the gross volume in order to derive therefrom the "carrying capacity" in terms of space unit. All the space is not measured at present, therefore, some portions not being available as passenger or cargo spaces. Such space might be deducted from the gross tonnage in order to find the earning capacity or might be omitted from measurement; both methods are in fact employed. The definition might properly read, therefore, "gross tonnage is an attempt to express an understood part of the internal cubical capacity."

General Nature

Gross tonnage is the product of centuries of development in various countries and the result is a diversity of methods as illogical as it is unjust. As is the case with many commercial usages, custom and precedent have prevented the adoption of a uniform standard which would be beneficial to all. The earliest rule was

$$\frac{L \times B \times D}{100} = \text{gross tonnage}$$

This was manifestly incorrect as the vessel had curved and not

straight sides. It better measured, *proportionately*, however, the respective volume of individual vessels than some later rules. This was followed by the introduction of a divisor, the rule being

$$\frac{L \times B \times D}{94}, \text{ or } \frac{L \times B \times D}{95},$$

a refinement of the same principle. On the assumption of a fixed relation between breadth and depth, and to facilitate the measurement of vessels loaded and afloat the rule was amended to

$$\frac{L \times B \times \frac{1}{2} B}{94}$$

and to

$$\frac{(L - \frac{3}{5} B) \times B \times \frac{1}{2} B}{94}$$

in order to allow for rake and round of stem and stern. Such a rule, with a divisor of 95, existed in the United States until the adoption of the Moorsom system. Internal measurements have uniformly been used, although a system based on outside measurements was proposed by the English Commission of 1849. Improved mensuration showed, however, that the internal volume could be more accurately found by Simpson's rule for ascertaining plane areas bounded by parabolic curves, and this was the basis for all national measurements after 1854.

Early rules and early laws often adopted total gross tonnage as a basis of measurement, but later it became customary to exempt from measurement certain spaces. Thus allowance was made for the rake of stem and stern, divisors were modified to obtain desired reductions in tonnage, allowances were made for engine-room space and space used for storage of sails, spaces not "permanently closed in" were exempted and also spaces devoted to the use of the crew. The effect of these will be seen later as we encounter them in the process of measurement. It is sufficient to say that in the present United States rules water-ballast space. spaces not "permanently closed in," passenger accommodations, hatchways, spaces connected with the operation of the vessel and for the use of the crew are wholly or partially exempt from measurement.

Divisions in the Measurement of Gross Tonnage

Before proceeding to the process of measurement it will be conducive to clearness to point out that it contains some well-marked subdivisions. The gross tonnage is the sum of the following items:

1. **Under-deck Tonnage.**— The capacity of the vessel below the tonnage deck.

2. **'Tween-deck Tonnage.**— The capacity of the spaces between the decks above the tonnage deck. The capacity between the second and upper deck and between the upper and shelter decks in a vessel with three decks and a shelter deck.

3. **Superstructures.**— The capacity of "closed-in" structures above-deck, including forecastle, bridge, poop, deck houses, chart houses, "closed" shelter decks, etc.

4. **Hatchways.**— The capacity of hatchways in so far as it exceeds ½ of 1 per cent of the gross tonnage.

It is also necessary to note the three ways in which spaces are treated in the measurement process. According to method spaces may be classified as follows:

1. **Included Space.**— A space which is measured in calculating gross tonnage. For example, the space under the tonnage deck and 'tween-deck spaces. It *may* be deducted later, as for example, the allowance for propelling space.

2. **Exempted Space.**—A space not measured in calculating gross tonnage. For example, the wheel house and "open" shelter decks.

3. **Deducted Space.**— A space included in the calculation of gross tonnage and later deducted from same. The deduction is sometimes limited to less than the space originally included, for instance, allowance for crew space.

Process of Measurement under United States Rules

1. **The Tonnage Deck.**— The tonnage deck is the upper deck in vessels with less than three decks. In vessels with three decks or more it is the second deck from below. In three-deck vessels the lower deck is often omitted and there is merely space for the same so that the first actual deck becomes the "tonnage" deck. The American rules state "In all other cases" (other than ves-

sels with three or more decks) "the upper deck of the hull is to be the tonnage deck." In a two-deck vessel a spar or awning deck apparently might conceivably be the tonnage deck, but this is not of much practical importance.

2. Length.— The length for tonnage purposes is measured along the upper side of the tonnage deck from stem to stern. By stem is meant the inside of the inner plank at the side of the stem and by stern the inside of the plank on the stern timbers. In making this measurement, since the distances are actually taken slightly above the prescribed place, allowance must be made for the rake of the stem and stern through the thickness of the deck and the rake of the stern through one-third of the round of the beam. The tonnage length is shown in the diagram by the line AB and it will be noted that the tonnage length differs from the register length, which is measured from the fore part of the outer planking on the side of the stem to the after part of the main sternpost. The English "New Measurement" rules of 1835 took the tonnage length at half the midship depth from the after side of the stem to the fore side of the sternpost but in recent years the tonnage length has never been the subject of much discussion and is similarly measured under the rules of France, England, and Germany.

3. Divisions of Length.— The tonnage length having been ascertained, the vessel is divided into sections for the purpose of measurement; the greater the length the greater the number of sections required, for the curves of a vessel's sides will vary with its length, and other things being equal, the greater the number of subdivisions the more accurate the measurement. The tonnage length is to be marked off in equal parts, the number of equal parts for vessels of various lengths being as follows:

Tonnage length (feet)	Equal parts
50 or under	6
51 to 100	8
101 to 150	10
151 to 200	12
201 to 250	14
251 and over	16

At each of the points of division so ascertained the area of a transverse section is to be found. This system is also followed in

France, England, and Germany, though the number of divisions vary in these countries. The divisions for a vessel of over 250 feet are indicated as C1, C2, C3, etc., on Diagrams 60 and 62.

4. **The Area of Transverse Sections.**— The object of dividing the tonnage length was to mark a number of points at which to measure the area of transverse vertical sections. The areas of these sections depend upon the depth of the ship, which is not

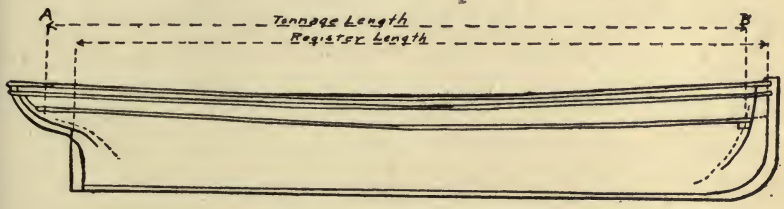


FIG. 59.— TONNAGE LENGTH

necessarily the same throughout the length of the vessel, and upon the breadth of the ship, which diminishes as the vessel rounds off toward the keel. Several depths and breadths must be measured, therefore, and this justifies the division of length referred to above. At each of the points of division (C1, C2, etc., on Diagrams 60 and 62) the depth of the vessel is measured by a measuring stanchion consisting of two rods attached to each other so that their united length may be increased or decreased. Such depths are indicated by the lines CD on Diagram 60. These depths are measured from a point at a distance of one-third of the round

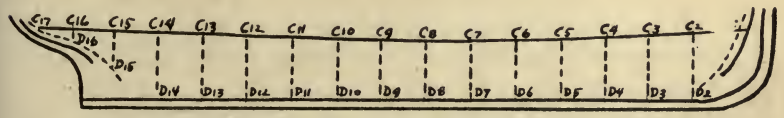


FIG. 60.— DIVISION OF TONNAGE LENGTH AND DEPTHS

of the beam below the deck to the upper side of the floor timber. The round of the beam may be ascertained by stretching a line across the deck from side to side at equal height from the deck on each side so as just to touch the crown of the deck at the middle line (see Diagram 61). In steel ships floor plates are found instead of floor timbers, and in vessels with double bottoms the measurement is made to the inner plate of the double bottom so that the space for water ballast is not measured, provided it is

not available for the carriage of cargo, stores, supplies, or fuel. In oil-burning vessels it is, of course, usually available for fuel. The average thickness of the ceiling is deducted. One of the depths so arrived at is indicated by the line CD in Diagram 61. Then if the depth at the middle division of the tonnage length does not exceed 16 feet divide each depth into 4 equal parts, and if said depth does exceed 16 feet divide each depth into 6 equal parts. These points of division are marked E, F, G, H, I, J and K on Diagram 61, and at each of said points the breadth of the vessel is to be measured, giving the lines marked LM, NO, PQ,

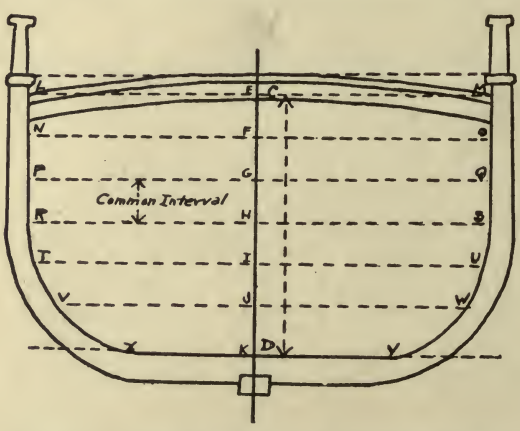


FIG. 61.— MEASUREMENTS OF TRANSVERSE SECTION

RS, TU and VW, on Diagrams 61 and 62. We now have the data necessary to ascertain the area of the vertical transverse section at each point of division of the tonnage length, C1, C2, C3, etc. This is accomplished by the use of Simpson's rule, which will be next described.

5. Simpson's Rule.— Divide the base into an even number of equal parts. Through the points of division and at the extremities draw ordinates to the curve perpendicular to the base and measure their lengths. These ordinates will consequently be odd in number. Multiply the length of each of the even ordinates by 4, and each of the odd ordinates by 2, excepting the first and last, which multiply by 1. The sum of these products multiplied by one-third of the common interval between the ordinates will give the required area. In the vertical transverse section at

each division point in the tonnage length of the vessel we have an area which may be measured by the foregoing rule with approximate correctness. The ordinates referred to are the breadths of the vessel measured at different depths and the depth is the "base" referred to. Suppose we take a midship transverse section for illustration and find it to have the dimensions indicated

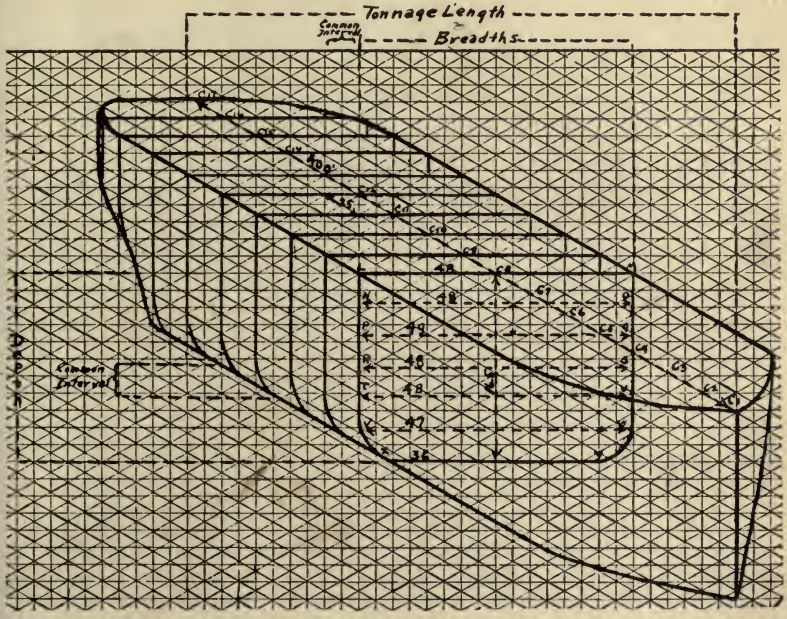


FIG. 62.— TRANSVERSE SECTIONS

in Diagram 62. The breadths are numbered 1, 2, 3, 4, 5, 6, and 7, starting from above and these breadths are, respectively, 48, 48, 49, 48, 48, 47, and 36 feet. Multiplying the even-numbered

Breadth (feet)		Multiplier		Product
48	×	1	=	48
48	×	4	=	192
49	×	2	=	98
48	×	4	=	192
48	×	2	=	96
47	×	4	=	188
36	×	1	=	36
				850

breadths by 4 and the odd-numbered breadths by 2, except the 1st and 7th, we obtain the results stated above.

The depth of the midship section was 16.5 feet which was divided into 6 parts, giving a common interval betwen division points of 2.75 feet. One-third of this common interval is 1.37.

Therefore, $1.37 \times 850 = 1164.50$ square feet.

This is the area of the midship vertical transverse section. In the vessel in question, having a length of over 250 feet, there are 17 division points on the tonnage length and consequently 15 such sectional areas to be measured, but the calculation is exactly the same for each as the above.

6. **Calculation of Principal Volume.**— Let us assume that the vertical transverse sections, as measured by the foregoing method, show areas as follows, reading from stem to stern:

Section	Area in sq. ft.
C1	0
C2	370
C3	680
C4	890
C5	1000
C6	1080
C7	1120
C8	1160
C9	1160
C10	1080
C11	1000
C12	900
C13	750
C14	575
C15	400
C16	200
C17	0

These areas are numbered from 1 up, from stem to stern, and Simpson's rule is again applied. The 1st and 17th areas are multiplied by 1, every other odd-numbered area by 2 and every even-numbered area by 4, giving the result in the table below.

The length of the vessel may be assumed to be 400 feet, and its division into 16 equal parts makes the common interval between the division points 25 feet. One-third of this common interval is 8⅓ feet. Multiplying the product obtained above by one-third of the common interval we get

$$8\tfrac{1}{3} \times 37{,}280 = 310{,}542 \text{ cubic feet}$$

Section	Area	Multiplier	Product
C1	0	1	0
C2	380	4	1520
C3	680	2	1360
C4	890	4	3560
C5	1000	2	2000
C6	1080	4	4320
C7	1120	2	2240
C8	1160	4	4640
C9	1160	2	2320
C10	1080	4	4320
C11	1000	2	2000
C12	900	4	3600
C13	750	2	1500
C14	575	4	2300
C15	400	2	800
C16	200	4	800
C17	0	1	0
			37280

as the principal volume of the vessel. Since the Moorsom ton is equivalent to 100 cubic feet of space, the tonnage under the tonnage deck of this vessel is about 3105. This is the register tonnage of the vessel subject to certain later additions and deductions, which in this particular vessel are extensive.

7. **Between-deck Tonnage.**— While the rules of various nations are substantially similar for the calculation of the tonnage below the tonnage deck, so that such tonnage is practically identical by all systems of measurement, the rules for calculating 'tween-deck tonnage differ considerably.

At this point it is necessary to notice the discrepancy in measurement which has arisen from the different interpretations placed upon the expression "permanently closed in" and similar phrases, a discrepancy as great as that occasioned by any other feature of measurement. The Moorsom Act of 1854 in Great Britain provided for the measurement of "permanent closed-in spaces," and these were uniformly measured until by 1860 vessel-owners were clamoring for the exemption of various kinds of superstructures and the space under what is now known as a "shelter deck." The decision in England in the *Bear* case in 1875 held that the shelter deck was not practically a complete deck for all purposes of safety to the ship and cargo. Thereafter shelter-deck space

was exempt from measurement under British rules. The present condition in the United States is well illustrated by a quotation from the Customs Regulations:

> By closed-in spaces is to be understood spaces which are sheltered from the action of the sea and weather, even though openings be left in the inclosure. Measuring officers will exercise due vigilance that the intent of the law in this respect is not evaded. It should be borne in mind, however, that no closed-in spaces above the upper deck to the hull are to be admeasured unless available for cargo or stores or the berthing or accommodation of passengers or crew. . . . Whether for the purpose of measurement a deck is to be regarded as an upper deck or as the shelter deck is to be determined in each instance both by the character and structural conditions of the erection, and by the purpose to which the between-deck is devoted.

What the real "intent of the law" is has yet to be discovered, but the practical result is that not all space is measured and yet until recently vessels were not as leniently treated as under British measurement.

8. Method of Measurement of Between-Deck Spaces.— The space above the tonnage deck and under the upper decks of the vessel is measured by an abbreviation of the system applied to the section below the tonnage deck — in brief, the use of only one breadth at each division point on the tonnage-length instead of five or seven. The length between decks is taken at the middle of the height of the 'tween-deck space, from inside of stem to inside of stern (line AB, Diagram 63). This length is divided into the same number of equal parts as the tonnage deck and at each of the points of division *one* breadth is measured (indicated by CD, EF, GH, IJ, KL, etc., on Diagram 63). The application of Simpson's rule to these breadths will give the area of an imaginary deck midway between the tonnage deck and the upper deck. This multiplied by the average height between the two decks will give the cubic contents in feet and the tonnage is ascertained by dividing this result by 100. If there are more than three decks the tonnage between other decks is ascertained in the same manner.

9. Superstructures and Closed-in Spaces.— In addition to the space between decks the vessel may contain a forecastle, bridge, poop, side houses, deck houses, spaces for steering gear, etc., above decks. The method for measuring the contents of such spaces

is an abbreviation of that used for 'tween-deck spaces. At the middle of the height the mean length is ascertained and divided into an even number of equal parts approximately the size of the divisions of the tonnage length and at each of such points of division, at the middle height, breadths are measured. To the sum of the end breadths add four times the sum of the even-

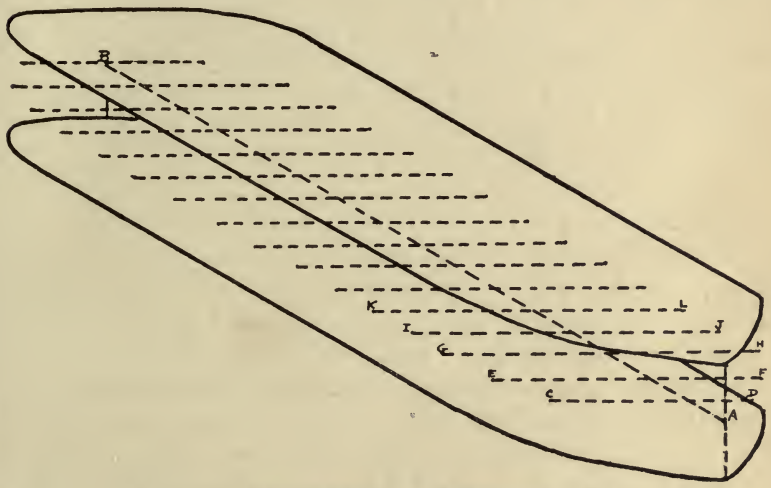


FIG. 63.— MEASUREMENT OF 'TWEEN-DECK SPACES

numbered breadths and twice the sum of the odd-numbered breadths and multiply the whole sum by one-third of the common interval between the breadths. The result is the approximate area of an imaginary horizontal plane midway between the deck and the roof of the superstructure which, multiplied by the mean height of said superstructure, gives the area of the same in cubic feet. No space is measured, however, which is open to the weather and not inclosed.

We have indicated the method of measuring spaces below the tonnage deck, spaces between the tonnage and upper decks and superstructures above decks, and it now remains to indicate those spaces which are exempted from measurement, whether below or above the tonnage deck.

10. **Spaces Exempt below the Tonnage Deck.**— These are principally spaces between ribs and floor beams since their use for cargo is restricted and water-ballast spaces available for no other purpose.

11. **Spaces Exempt above the Tonnage Deck.**— These are excluded from gross tonnage, either because they are not enclosed, or by reason of their use for a purpose which makes them unavailable for cargo or passengers. They contribute nothing to the earning capacity of the vessel.

a. *Spaces Exempt because Unenclosed.*— It is the almost universal rule to exempt the space occupied by hatchways up to ½ of 1 per cent of the gross tonnage and to measure all space used for this purpose in excess of this amount. Permanent erections with openings in the sides or ends, unavailable for cargo or passenger use, are exempt.

b. *Spaces Exempt because of Their Purpose.*— In addition to unenclosed spaces it has been customary for many years in all countries to exempt from measurement certain spaces which were not available for the carriage of cargo or passengers or were mere conveniences for the latter.

(1) Water-Ballast Space.— Water-ballast space above the tonnage deck is comparatively unusual. Any such space is included in gross tonnage. A notable case of water-ballast above the tonnage deck is the self-trimming vessel described in Chapter V.

(2) Machinery Spaces.— The space occupied by a donkey engine and boiler is measured if below decks but exempt if above decks and not connected with the engine room. If so connected it is measured although deducted later in arriving at net tonnage (see next chapter). Above the crown or top of the actual engine-room a closed-in space is frequently provided for light and air purposes. This space is not added to the gross tonnage ordinarily but may be if the owner so requests and it is reasonable in extent, above the upper deck, safe and seaworthy, and cannot be used for any purpose other than machinery or the admission of light or air to the machinery or boilers. The incentive for measuring this space would be a decreased net tonnage through having it considered as engine-room space in the deduction for propelling space later. The defects of this method of treatment are obvious. It not only makes the rules confusing and subject to misinterpretation, but, in addition, allows the shipowner to select a treatment which will be beneficial to him, instead of prescribing a rule equitable between all classes of vessels. The mathematical results are discussed in the chapter on net tonnage.

(3) Navigating Spaces.— The spaces for the anchor gear,

steering gear, and capstan are included in the gross tonnage when situated below the upper deck and exempted when above said deck. In the former case, however, they are subsequently deducted, giving the same net result as if they had never been measured. The chart, lookout, and signal houses are measured and the wheel house is exempted by the United States.

(4) Passenger and Crew Accommodations.— Cabins and staterooms located on the upper deck to the hull are included in the gross tonnage, but temporary arrangements to shelter passengers on short voyages are exempted with the consent of tonnage officials. This brings to attention a rule peculiar to the United States, providing that the space of cabins and staterooms for passengers constructed entirely above the first deck which is not a deck to the hull are not to be measured or included in gross tonnage. This provision was originally intended as a benefit to coasting and river steamers, ocean vessels then having no such construction, but when the latter added several passenger decks above the upper deck to the hull, they took advantage of the unrestricted wording of the provision.

Skylights and domes are exempt while galleys, cookhouses, condenser and bakery spaces are exempt if situated above decks and measured if below decks, but in the latter case are available for deduction. Companion houses are exempt except when used for smoking room or other special purposes. Passageways are measured under the American rules when serving measured spaces and may be deducted when serving deducted spaces. Toilet facilities for officers and crew, under American rules, are exempted if above decks and measured and deducted if below-decks. Other toilets below decks are measured without privilege of deduction. Above-decks 1 toilet per 50 passengers, not exceeding a total of 12, is exempt.

12. Principles Governing Gross Tonnage Measurement.—

a. *What It Includes.*— Under the very old rules gross tonnage did not include superstructures but there were practically none in existence. After the change in vessel construction and the introduction of the Moorsom system the gross tonnage included the cubic capacity below the tonnage deck, between the tonnage and upper decks, and in the superstructures, with certain exemptions which varied with time and place of measurement.

b. *Gross Tonnage Represents Total Cubic Capacity.*— We have seen that the gross tonnage only roughly represents the total cubic capacity of the vessel, though such is theoretically its purpose. Exemptions based on logic, precedent, and the desire to minimize the tonnage upon which dues were payable all contributed to defeat the theory, and even the Panama rules, the strictest in existence and with the avowed object of measuring all spaces, in fact allow some exemptions.

c. *Inclusions and Deductions.*— The gross tonnage of a vessel is determined by inclusions and exemptions. It might be wondered why certain items are included in the gross tonnage only to be later deducted in arriving at the net tonnage. The answer is that while the result so far as net tonnage is concerned is the same, to reach this result by omitting spaces from the gross tonnage would be to underestimate the latter. Furthermore, the inclusion of as much space as possible in gross tonnage renders easier the calculation of net tonnage under any of the rules, since spaces not measured under any particular set of rules can be readily deducted, but spaces omitted from consideration must be measured and accounted for, entailing extra labor and time.

d. *Principal Factors in Gross Tonnage.*— The items which have been differently treated by various rules and which consequently principally account for the wide discrepancies in results attained are the interpretation given to the word "closed-in" in connection with decks and superstructures, the exemption of tiers of cabins and staterooms above the first deck which is not a deck to the hull, the varying treatment of engine-room light and air spaces, spaces contributory to the feeding and comfort of the crew and passengers and passageways.

e. *The Relative Strictness of Different Rules.*— Naturally all the rules do not give the same gross tonnage for the same vessel. In 1911 an application of the British, Suez, and American rules to eight vessels showed that these vessels averaged 5216 tons under the British rules, 5464 tons under the Suez rules, and 5581 tons under the American rules. The latter exceeds the former two results largely by reason of the interpretation of closed-in spaces. The measurements under the Panama rules would yield a greater result than any of the above, while German results are closely comparable with British.

f. *Exemptions Prevalent Causes of Difficulty.*— Illustrations of this fact are found in the *Bear* case in Great Britain where the exemption of the space under shelter decks has caused confusion between British and other rules to the present day, and has had a world-wide influence in retarding the scientific measurement of vessels; in the British *Isabella* case where light and air space not included in gross tonnage was held to be deductible; in the American requirement that higher cabins and staterooms be exempted while lower ones were measured; in the efforts of the Suez Canal Company to obtain an equitable international basis for the measurement of vessels of different nationalities using the canal. In formulating the rules for the Panama Canal their author stated:

> The logical procedure and the only one by which an accurate net tonnage can be calculated is to include in gross tonnage the entire closed-in capacity of a vessel and to deduct therefrom, in calculating net tonnage, such navigation and other spaces as are not available for the accommodation of passengers or for the stowage of cargo.

g. *Gross Tonnage and Earning Capacity.*— Two vessels might have the same gross tonnage but by reason of low engine power considerably more space might be available in one for cargo. In a passenger steamer and a freight steamer of equal gross tonnage considerable space on the former would be devoted to comfort and speed and contribute nothing to earning power. Passenger vessels with superstructures for passengers would be entitled to considerable exemption, while passenger space below decks is all measured. Gross tonnage would measure engine-room, boiler, and fuel space, although this is only partly contributory to earning power and its proportion to gross tonnage varies greatly. Therefore net tonnage is far more frequently used as a basis for vessel charges and tolls than gross tonnage.

h. *Defects of American Rules.*— The American rules yield results which have neither the merit of correctly measuring the cubic capacity nor the profit of sufficiently understating the tonnage of their own vessels. The British and German rules at least do the latter. On the one hand, passenger accommodations above the first deck which is not a deck to the hull and certain navigation spaces above the upper deck and deck loads are exempt, while, on the other hand, "closed-in" spaces have been more strictly construed than under the rules of foreign nations.

CHAPTER XI

NET TONNAGE

Gross tonnage approximately measured the closed-in capacity of a vessel; net tonnage measures its capacity for passengers or cargo. It is, therefore, the gross tonnage less certain deductions, principally space required for machinery, fuel and the crew. The machinery and fuel space is often measured by a somewhat arbitrary method so that the deduction is in excess of the actual space occupied, but this will be seen to be a difficulty inherent in the character of the space measured. The deductions may be divided into three groups, which will be treated in the order given: deductions for propelling machinery, for crew space, and for navigation spaces.

Measurement of Propelling-Power Space.— The measurement of the space occupied by propelling machinery includes (*a*) machinery and boiler space, (*b*) ventilating space, and (*c*) shaft tunnel. By reason of an option allowed the vessel-owner under the American rules it is always necessary to measure the engine room, whatever its size may be. The content of the three spaces referred to is considered to be the product of the mean length, breadth, and depth of such spaces divided by 100. From the engine-room space proper is to be deducted the cubical capacity of any cabins or storerooms which may be fitted in the engine room and also any space occupied by machinery not used in propelling the ship.

It will be noticed that no mention has been made of the very considerable space required for coal. An Atlantic liner may burn from 500 to 700 tons of coal per day and her bunkers must be capable of holding from 4000 to 6000 tons, a cubic capacity of 180,000 to 270,000 cubic feet or 2700 register tons. Two kinds of coal bunkers are in use: side bunkers formed by partitioning off the space beside the engine and boilers amidships and cross bunkers, formed by partitioning off a portion of the hold entirely across the ship approximately amidships. Both the

machinery and coal bunkers are ordinarily situated amidships because in this position the consumption of coal during the voyage does not cause a constantly increasing trim by the head. But in oil steamers, where oil is used as fuel, the machinery may be situated in the stern and the fuel carried both fore and aft in the peak and double bottom tanks. But it is obvious that the amount of space required for fuel is both indeterminate and changing. It will depend upon the duration of the voyage and the possibility of frequently and economically replenishing the supply. It will also be affected by the efficiency of the machinery, whose inferiority may increase the coal consumption by as much as 20 per cent, and by the quality of the fuel. The vessel engaged in the line trade, with definitely fixed voyages, may be able to calculate fairly accurately the necessary fuel, while the tramp vessel must always allow a considerable margin for contingencies. These considerations led to fitting vessels with movable partitions, enabling the bunker to be enlarged or contracted as necessity requires and the same space to be used indiscriminately for fuel bunkers or cargo. It is therefore impossible definitely to designate the fuel space and accurately measure the same, and it can only be assumed that the fuel space will, on the average, be proportionate to the engine-room space.

Light and Air Spaces.— Because of the peculiar consideration given to light and air spaces it is necessary to consider these separately. It will be recalled that the space above the crown or top of the actual engine-room space, provided for purposes of light and air, is not ordinarily included in the gross tonnage, but may be if the owner so requests. If included in the gross tonnage it may also be added to the engine-room space so as to increase this space and consequently the deduction allowed for it.

Deductions for Propelling Space.— The American rules combine two forms of allowance for propelling-power space. Let us consider screw-propelled vessels exclusively. If the measurement shows the actual space occupied by the engine room including the shaft tunnel to be 13 per cent or less of the total gross tonnage of the vessel, 1¾ times the tonnage of the space actually so occupied shall be deducted from the gross tonnage in order to arrive at net tonnage. This is the so-called Danube principle, the allowance for fuel space being a percentage of the engine-room space. If, however, the space actually occupied by

the engine room, including the shaft tunnel, proves to be over 13 per cent but less than 20 per cent of the total gross tonnage there shall be deducted 32 per cent of the gross tonnage of the vessel. This is the so-called percentage principle, the allowance for fuel space being a percentage of the gross tonnage of the vessel. If, in the third place, the engine-room space totals 20 per cent or over of the gross tonnage of the vessel the allowance shall be either 32 per cent of the total gross tonnage or 1¾ times the actual space, as the owner may prefer. This gives a choice, when the tonnage of the actual space exceeds 19.99 per cent of the gross tonnage, of the percentage or Danube principle. The following extract from Walton's *Know Your Own Ship* will show the significance of these provisions:

> So far as ordinary screw steamers are concerned, the modern shipbuilding practice is to arrange that the tonnage of the machinery spaces, either independently or together with a part or the whole of the light and air spaces above the upper deck, amounts to at least 13 per cent of the gross tonnage. To design the machinery spaces of such vessels so that their aggregate tonnage amounts to less than 13 per cent of the gross tonnage causes the propelling space deduction to be estimated at 1¾ of the total actual machinery space, as previously stated. This produces a comparatively small propelling space deduction. For instance, suppose we have a screw steamer of 100 tons gross tonnage. If the actual propelling space amounts to just over 13 tons of measurement, then the deduction is 32 tons; but if the propelling space measurement reaches only 12½ tons, then the deduction is only 1¾ of 12½, or 21.87 tons. On the other hand, nothing is to be gained by enlarging the engine and boiler spaces so long as they do not exceed 20 per cent of the gross tonnage. When, however, 20 per cent is reached or exceeded, it has been shown (see below) how preferable is the deduction of 1¾ times the actual machinery space measurement to that of 32 per cent of gross tonnage.
>
> Suppose the gross tonnage of a screw steamer be, say, 100, and the actual propelling space 20. The deduction of 1¾ times the actual propelling space would be 1¾ of 20, or 35, which is greater than 32 as a deduction. . . . It can now easily be understood how, in vessels with large propelling space, the register tonnage is sometimes relatively small, especially when the crew spaces and other deductions are also large.

The following table gives a summary of the treatment of propelling-power spaces for both screw and paddle-wheel steamers under the American rules.

Type of steamer	Percentage of propelling-power space to gross tonnage	Deduction
Paddle-wheel	20 per cent or under	150 per cent of actual space
	Over 20 and under 30 per cent	37 per cent of gross tonnage
	30 per cent or over	37 per cent of gross tonnage or 150 per cent of actual space
Screw	13 per cent or under	175 per cent of actual space
	Over 13 and under 20 per cent	32 per cent of gross tonnage
	20 per cent or over	32 per cent of gross tonnage or 175 per cent of actual space

This is further illustrated by the accompanying diagram in which the rising line indicates the increasing deduction for a rising

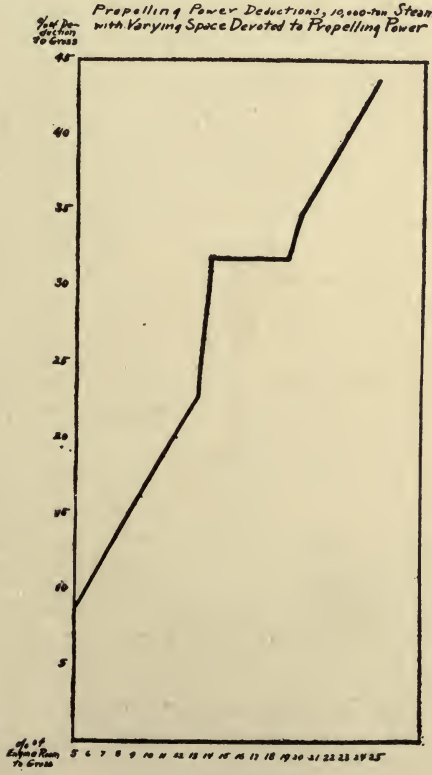


FIG. 64

ratio of propelling-power space to total gross tonnage in a 10,000-ton steamer.

It will be noted from this diagram that a ratio of propelling space to gross tonnage anywhere below 13.1 per cent entails a deduction proportionate to the propelling space, but that at 13.1 per cent the deduction abruptly jumps from 22.75 per cent of gross tonnage to 32 per cent of the same. Where the propelling space would naturally approach 13 per cent, therefore, the tendency is to make it 13.1 per cent in order to obtain the larger deduction. But there is no incentive to make it greater than 13.1 per cent, for, even though it be increased to 19 per cent, the deduction is exactly the same. When the ratio of propelling space to gross tonnage becomes 20 per cent, however, assuming the owner take advantage of his option, the deduction may be abruptly increased to 35 per cent, and thereafter the deduction is proportionate again to the amount of propelling-power space. There are thus three sections of the curve on the diagram, two of which are proportionate to propelling-power space and one proportionate to the gross tonnage of the vessel. It is difficult to see how these can be logically or economically justified. In the succeeding chapter we shall see how propelling-power space is treated under the laws of other nations and particularly the Panama rules.

Deductions for Crew Space.—The term "crew" includes the entire personnel on the articles and crew list — sailors, firemen, mechanics, petty officers, officers, doctors, stewards, etc., and the spaces involved are the sleeping quarters, lavatories, bathrooms, toilets, wardrooms, galleys, shelter for condensing water, chief engineer's office, wireless office, mess rooms and passages exclusively serving these spaces. All of the space so occupied is to be deducted from gross tonnage, unless used by or for passengers. But depending upon the date of construction of the vessel, the law requires a space of from 72 to 100 cubic feet and from 12 to 16 superficial feet to be allotted to each seaman or apprentice, and requires also that suitable, clean, and sanitary spaces be allotted for other requirements of the crew. No deductions from tonnage will be made unless there is permanently cut in a beam and over the doorway of every such place the number of men it is allowed to accommodate. It will be recol-

BRITISH STEAMSHIP *Stephen*
(Particulars given on p. 211)

	TONNAGE as given by following certificates:		
	United States	British	Suez
Under tonnage deck	3607.36	3607.36	3607.36
Forecastle	84.92	84.92	.....
Bridge space	303.10	303.10	347.07
Poop	177.78	177.78	.....
Side houses	7.62	7.62	2.52
Deck houses	196.78	196.78	115.26
Light and air	57.28	57.28	.....
Upper 'tween-decks added.	968.94	.....	1256.41
Light and air added	54.99	.....	.....
Excess hatchways added	11.55	.....	31.87
Galleys, cook-houses, water-closet, bath, chart house, wheel house, etc	.....	.....	117.21
Gross tonnage	5470.32	4434.84	5477.70
DEDUCTIONS			
Propelling power, 32 per cent	1750.50	1419.15	.....
Actual plus 75 per cent	.....	.....	1102.73
Crew space	141.27	141.27	.....
Doctor, engineers, etc.	.....	.....	16.46
Officers	.....	.....	36.81
Master	9.22	9.22	.....
Boatswain's stores	17.71	17.71	.....
Chart house	4.73	4.73	4.73
Water-ballast spaces	34.91	34.91	.....
Galleys, cook-houses, water-	.....	.....	16.11
Wheel house	.....	.....	6.30
Steering gear	.....	.....	28.28
Wireless apparatus	.....	.....	7.37
Total deductions	1958.34	1626.99	1274.40
Net tonnage	3511.98	2807.85	4203.30

lected that many such spaces are exempt if above decks and we now find that when below decks, although measured, they are deducted. Likewise, any properly constructed and reasonable space for the use of the master of the vessel is deducted. These

spaces are measured by taking the product of the three dimensions when bounded by practically flat surfaces and in other cases by the Moorsom system.

Deductions for Navigation Space.— These include any spaces devoted exclusively to the working of the helm, the capstan, and the anchor gear; or spaces used for keeping the charts, signals, and other instruments of navigation, and boatswain's stores; and the space occupied by the donkey engine and boiler, if connected with the main pumps of the ship. In the case of a vessel propelled wholly by sails there may be deducted a space for the storage of sails, not exceeding 2½ per cent of the gross tonnage. All such space must be permanently marked "Certified for . . . (boatswain's stores, chart house, etc.). . . ."

The preceding table shows the calculation of tonnage items for a common type of vessel on three tonnage certificates.

Principles of Net Tonnage

Reviewing the facts presented in this chapter the following principal features of net tonnage are noted:

1. Net tonnage consists of gross tonnage less deductions for propelling space, crew space, and navigation spaces. There is no unanimity among nations as to the method of arriving at the total deductions.

2. Net tonnage represents theoretically the earning capacity of the vessel, the theoretical purpose being defeated by arbitrary rules for engine-room deductions and the desire to favor native vessels.

3. Net tonnage is affected by the inclusion and exclusion of items from the gross tonnage and by deductions from gross tonnage. Thus, the exemption of shelter-deck space from measurement affects both gross and net tonnage, while the character of the machinery-space deduction affects only the net tonnage. It is apparent that the correct net tonnage can be arrived at only by accurately ascertaining the gross tonnage and making fair deductions for machinery, crew, and navigation spaces.

4. The most important provision of a code of tonnage rules is that determining the deduction for propelling-power space, for this forms from ¾ to ⅚ of the total deduction made. The deductions for crew and navigation spaces comprise from 15 to 25 per cent of the total deduction.

DEPARTMENT OF COMMERCE
BUREAU OF NAVIGATION
PART I.—"Measurement of Vessels," 1919

TONNAGE

Register Length 39.0.0

Register Breadth 5.4.2

Register Depth (Midship Section) 2.7.8

Height under Spar Deck .....

	SECTION 1.			SECTION
TONNAGE DEPTHS				2
Common Interval between Breadths to nearest hundredths of a foot				4
Number of Breadths.	Multipliers.	Breadths.	Products.	Breadths.
1	1			28.0
2	4			26.0
3	2			24.6
4				23.4

...ER REGISTERED

...rs cubic .....

Anchor gear ..... Boat winches steam .....

Donkey engine and boiler ..... Radio house .....

Propelling power indicated speed ..... H

Total Deductions .....

● Net Tonnage. =

...paces, and no others, have been omitted in Forepeak, aft peak tank and other tanks as ...

...; open forecastle ..... open bridge ..... open pump ..... open shelter deck ...

...feet ..... steering gear ..... donkey engine and boiler ..... hoisting winches .....

... galley ..... condensers ..... water-closets ..... cubic .....

... having agreed to the description and admeasurement ...

...thing, to law said vessel has been duly registered at this Port ...

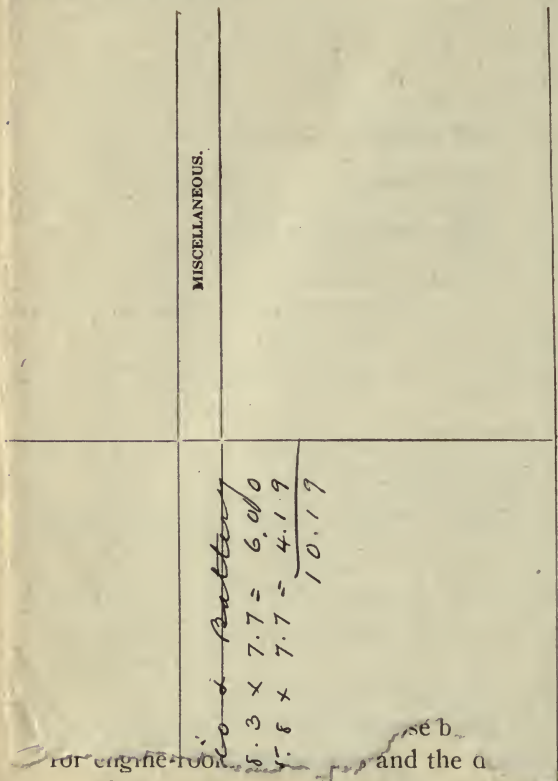
...n under my hand and seal, at the Port of ..... this .....

...in the Year One thousand Nine hundred and .....

PLACE FOR SEAL OF COLLECTOR

Deputy Official ..... Collector of Customs

FIG. 66.— TONNAGE CERTIFICATE



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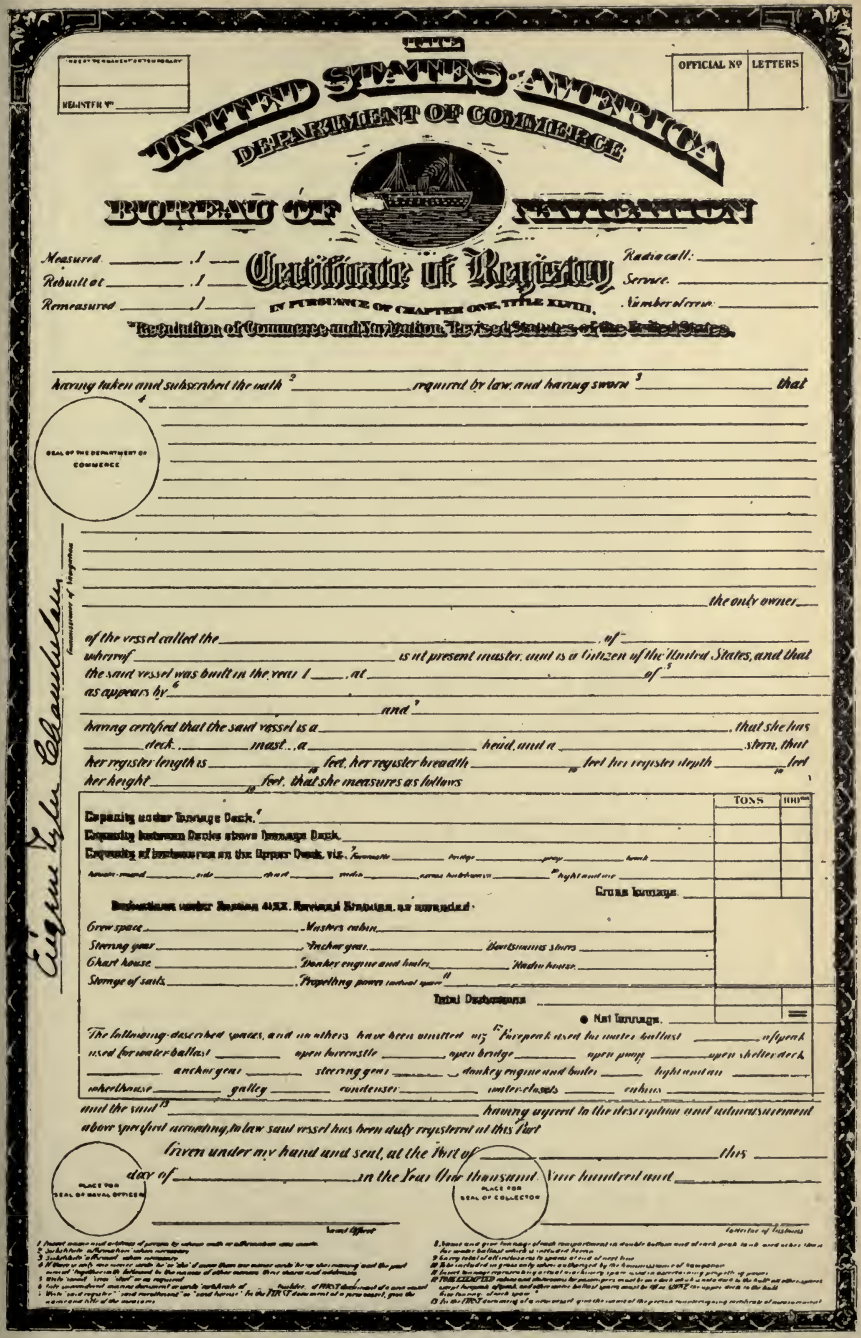
THE
UNITED STATES OF AMERICA
DEPARTMENT OF COMMERCE
BUREAU OF NAVIGATION
OFFICIAL Nº
LETTERS
REGISTER Nº
Measured ____ /
Rebuilt at ____ /
Remeasured ____ /
Certificate of Registry
IN PURSUANCE OF CHAPTER ONE, TITLE XLVIII,
"Regulation of Commerce and Navigation," Revised Statutes of the United States.
Radio call:
Service.
Number of crew:
having taken and subscribed the oath [2] ____ required by law, and having sworn [3] ____ that [4]
SEAL OF THE DEPARTMENT OF COMMERCE
the only owner
of the vessel called the ____ of ____
whereof ____ is at present master, and is a citizen of the United States, and that the said vessel was built in the year [1] ____, at ____ of [2]
as appears by [6]
and [7]
having certified that the said vessel is a ____, that she has ____ deck, ____ mast, ____ a ____ head, and a ____ stern, that her register length is ____ feet, her register breadth ____ feet, her register depth ____ feet, her height ____ feet, that she measures as follows [8]

	TONS	100THS
Capacity under Tonnage Deck. [9]		
Capacity between Decks above Tonnage Deck.		
Capacity of Deckhouses on the Upper Deck, viz.: [10]		
Gross Tonnage.		
Deductions under Section 4153, Revised Statutes, as amended:		
Crew space ____ Master's cabin ____		
Steering gear ____ Anchor gear ____ Boatswain's stores ____		
Chart house ____ Donkey engine and boiler ____ Radio house ____		
Storage of sails ____ Propelling power [11] ____		
Total Deductions		
Net Tonnage.		

The following-described spaces, and no others, have been omitted viz: [12] Forepeak used for water ballast ____ afterpeak used for water ballast ____ open forercastle ____ open bridge ____ open pump ____ open shelter deck ____ anchor gear ____ steering gear ____ donkey engine and boiler ____ light and air ____ wheelhouse ____ galley ____ condenser ____ inter-deck ____ cabins ____
until the said [13] ____ having agreed to the first option and otherwise conformed to the requirements of law, said vessel has been duly registered at this Port

Given under my hand and seal, at the Port of ____ this ____ day of ____ in the Year One thousand Nine hundred and ____

PLACE FOR SEAL OF NAVAL OFFICER

PLACE FOR SEAL OF COLLECTOR

Naval Officer

Collector of Customs

1 Insert names and address of persons by whom oath or affirmation was made.
2 Set forth the affirmation when necessary.
3 Set forth the oath when necessary.
4 If there is only one owner write "the" if more than one owner write "the several owners" and "respectively" before "is the owner" if there are two or more, give the name and title of the owners.
5 Name and give tonnage of each compartment in double bottom and of each peak tank and other space for water ballast which is excluded herein.
6 Give name of all enclosures to spaces shown as open.
7 Enter the words "and [illegible]" when a vessel is changed by the alteration or addition of tonnage.
8 Insert the words representing a fraction when any of the tonnages are expressed by fractions of 100.
9 THE STATUTES define and enumerate the spaces which are and which are not to be built up above the upper deck to be included in gross and to be allowed by the deductions of tonnage.
10 In the event of a new vessel, give the name of the person constructing, or number of measurement.
11 Steam, sail, or other motive power.
12 Insert the words "no spaces" when all the spaces are included.
13 In the event of a new vessel, give the name of the person constructing, or number of measurement.

Captain Tyler Edmondson
Commissioner of Navigation

FIG. 66.— TONNAGE CERTIFICATE

5. The Suez and Panama rules give the greatest net tonnage, being followed by the American, German, and British.

6. While there is confusion in the exemption and deduction of navigation spaces and the treatment of light and air spaces, it will later be seen that the deductions for propelling-power space are the principal cause of understatement of net tonnage and the variable net tonnage results under the different rules.

7. Net tonnage, which excludes a large number of spaces unusable for passengers or cargo, is evidently a much fairer basis for the assessment of vessel charges than gross tonnage, which would favor the slow vessels and cargo carriers at the expense of the high-powered and passenger vessels.

8. The American rules for ascertaining net tonnage are defective in that they use the unsatisfactory combination of percentage and Danube rules for ascertaining machinery-space deductions, allow light and air space to be either exempted or deducted, and do not treat crew and navigation spaces consistently.

Example of Measurement Calculations

Figures 65 and 66 are examples of an American tonnage certificate and a form for the calculation and recording of particulars of tonnage. On the face of the latter form will be noticed the particulars of the vessel, the measurements necessary for the calculation of tonnage, the tonnage under the tonnage deck, the inclosed spaces above the tonnage deck and spaces to be deducted, a summary of the tonnage and the surveyor's certificate. The reverse side is a continuation of the exempted and deducted spaces.

REFERENCES

1. Johnson, E. R.: "Report to Secretary of War on Panama Canal Traffic and Tolls." Washington, 1913. Chaps. III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII and XIV, Part III and Appendices 1–16, and 18. (A comprehensive discussion of the whole subject of tonnage measurement and its relation to canal tolls. Bibliography on tonnage measurement.)
2. Great Britain, "Report of Royal Commission on Tonnage," *Parliamentary Papers*. London, 1881, C-3074. In Reports from Commissioners, Vol. 49. (Reprinted in Reference 1.)

3. Great Britain, "Report of Board of Trade Committee, 1906." London, 1906, Cd-3045. (A discussion of deductions for propelling power.)
4. Herner, Heinrich: *Hafenabgaben und Schiffvermessung.* G. Fischer, Jena, 1912. (A discussion of the history of tonnage measurement in Germany and other countries, the German and Suez rules and vessel and port charges based on tonnage.)
5. Moorsom, G.: *Laws of Tonnage.* London, 1852. (A discussion of the principles upon which tonnage should be based, defects of then existing rules and a description of the methods later known as the Moorsom system.)
6. Moorsom, G.: "On the New Tonnage Taw." *Transactions of the Institution of Naval Architects,* Vol. I, pp. 128–144. London, 1860.
7. *Nautical Magazine.* London, 1889–1890, Vols. lviii and lix, pp. 1–15, 89–101, 173–186, 261–269, 356–367, 722–735, 804–824, 985–998, 1–11, 89–96. (A complete history of the development of tonnage measurement in Great Britain, and an explanation of the Moorsom system.)
8. White, W. H.: *Manual of Naval Architecture.* Murray, London, 1894. Chap. II. (Brief history of the development of tonnage measurement, early British laws and present British measurement, criticism of engine-room deductions, comparison of British and Suez rules, international tonnage, and alternative systems of measurement.)
9. "Report of the International Tonnage Commission, Constantinople, 1873." (Reprinted in Reference 1.)
10. Beret, V.: *"Etude sur le Jaugeage,"* report to the President. *Société anonyme de publications périodiques,* P. Mouillot, Paris, 1905. (History of tonnage, the Moorsom system, international tonnage, relation between tonnage and carrying capacity, principles and methods of Suez tonnage, comparative tables of British, German, and French measurement.) (Comparative tables and history of Suez measurement translated in Reference 1.)
11. Germany, Imperial Department of Interior: "The Measurement of Seagoing Vessels." Berlin, 1908. (German rules. Translated in Reference 1.)
12. Germany, Imperial Department of Interior: "Instructions for Ship Measurement." 1895. (Translated in Reference 1.)
13. Holmes, G. C. V.: *Ancient and Modern Ships.* Wyman & Sons, London, 1906. Vol. II, Appendix II. (Brief history of tonnage.)
14. Great Britain, Board of Trade: "Instructions and Regulations for Measurement of Ships and Tonnage." London, 1913. (British and Suez measurement, British tonnage laws.)

15. JOHNSON AND HUEBNER: *Principles of Ocean Transportation.* D. Appleton & Co., New York, 1918. Chap. IV. (Brief elementary discussion of tonnage measurement.)
16. WALTON, THOMAS: *Know Your Own Ship.* Griffin & Co., London, 1917. Chap. VIII. (Good summary of the present British, Suez, and Panama measurement systems.)
17. Suez Maritime Canal Co.: "Memorandum on Application of Rules of 1904." Paris, 1909. (Contained in Reference 1.)
18. United States, Navigation Laws, Sections 13–27. (Contained in Reference 1.)
19. United States, Customs and Regulations, Arts. 71–87. (Contained in Reference 1.)
20. United States, Department of Commerce, Bureau of Navigation: "Regulations for Measurement of Vessels, Measurement Laws and Suez Canal Regulations." Washington, 1919.
21. United States, Commissioner of Navigation: Annual Reports of 1914, 1915, 1916, 1917, 1919.

CHAPTER XII

COMPARISON OF MEASUREMENT RULES

The tonnage laws of various nations have differed from the earliest times. We have previously described some of the older rules for calculating tonnage, noting that they were dissimilar in various countries at the same time, undergoing changes with time in all countries and in the early periods even different in the same country at the same time, as evidenced by the local rule in Philadelphia about 1850. Constant but slow progress has been made toward uniformity with the result that, while various nations and the Suez Canal Company make their own measurement rules, these have constantly tended to become more harmonious.

Present-Day Rules

1. **Great Britain.**— Early British rules were mere approximations of the capacity of vessels, the estimates of two individuals as regards the same vessel in 1650 often differing by 30 per cent. The first measurement law was passed in 1694 and repealed in 1696 and another act of limited application was passed in 1719, but the first really important law was that requiring the use of "Builders' Old Measurement" rules in 1773. This act, which was in effect until 1835, was intended to express the tonnage of vessels in terms of dead weight. It was easily evaded and produced unseaworthy vessels, so that in 1835 the "New Measurement" law was passed, changing the rules from a dead-weight to an internal capacity basis and providing for a limited number of measurements in specified positions. This law, though subject to evasion, continued until the adoption of the Moorsom system in 1854, a system which forms the foundation for modern measurement rules, that of the United States included. The Act of 1854 had allowed an exemption from tonnage for crew houses on deck as an incentive to more suitable crew quarters. Small vessels in which this was impossible were placed at a disadvantage

and an act of 1867 provided that under certain conditions a deduction from tonnage should be allowed to the extent of the actual cubic content of all places occupied by the crew with the exception of the master. An amendment in 1889 provided that no deduction should be made from gross tonnage for any space which had not previously been measured, permitted the exemption of reasonable light and air spaces, and specified deductions for certain navigation spaces. Every seagoing vessel of over 15 tons burden must be registered and to obtain a certificate of registry must be surveyed and measured by a surveyor appointed by the Board of Trade, which is a government agency. This is done under rules and instructions issued by the Board of Trade, in accordance with the laws requiring the same. Irrespective of the British requirement, without this document the vessel would be detained for measurement at every port of call.

It is important to note that in 1862 a law was enacted in Great Britain providing that when any foreign nation adopted the British system of measurement under the Act of 1854 the tonnage of vessels as stated in their national certificates would be accepted at British ports without remeasurement. A special clause has been inserted in every tonnage act since this date, making it a part of the Act of 1854. This opened the way to international recognition of national tonnage certificates.

2. **Germany.**— In Germany a number of different rules for tonnage had been in use in the several German states, but in 1873 the Moorsom system became the official measurement method. The German tonnage differed from British, however, in respect to the deduction for propelling-power space and the treatment of shelter-deck space. In 1888 the German law was amended by increasing the number of transverse areas measured in large ships, fixing a sliding scale of allowances for crew and navigation spaces and for the exemption of hatchway space. In 1895 the percentage rule for propelling-power deductions was adopted. The measuring is conducted by measurement boards appointed by the State governments, supervised by the Bureau of Registry, which until the overthrow of the Imperial government was under the direction of the Imperial Chancellor.

3. **United States.**— A system somewhat similar to the "Builders' Old Measurement" rules of Great Britain was in force in the United States until the adoption of the Moorsom system in

1865. In a single-deck vessel by the Act of 1789 the tonnage was the product of (1) the length measured from the fore part of stem to the after part of sternpost less three-fifths of the breadth, (2) the breadth at the broadest part above the main wales, and (3) the depth from the under side of the deck to the ceiling in the hold, this product being divided by 95. For two-deck vessels the rule was similar except that one-half the breadth was substituted for the measured depth. This law was reënacted in 1799 and remained in force until 1864. Aside from increasing the number of transverse sections to be measured in calculating under-deck and superstructure capacity the Law of 1864 was exactly the same as the British Law. It was merely a gross tonnage law, however, no allowance being made for engine-room or crew space and foreign vessels paid tonnage dues upon gross tonnage until 1882. In 1865 the law was passed which exempted from measurement passenger cabins above the uppermost full length deck not a deck to the hull. In 1882 net tonnage was made the basis for tonnage taxes and the Danube rule was authorized for deducting propelling-power space. The allowable deductions for spaces above decks were increased in 1895, and the British rule for propelling-power deductions substituted for the Danube rule.

The Commissioner of Navigation has supervision over the measurement of vessels and the law requires that the vessel "shall be measured by a surveyor, if there be one, at the port or place where the vessel may be, and if there be none, by such person as the collector of the district within which she may be shall appoint." In practice this work is now done by men in the marine divisions in the custom houses, some of whom leave their tariff figures or statistical compilations to perform it. Necessarily their qualifications vary widely, and to promote uniformity only one adjuster is provided at a remuneration of $3500 per annum, including expenses. During the recent expansion in shipbuilding the appropriation for measurement purposes would have been insufficient had it not been for the constancy to type of many of the vessels on the Shipping Board program. This inefficient method of handling measurement is in startling contrast to the provision made in some foreign countries.

4. Suez Canal Company.— The Suez Canal was opened for navigation in 1869, and its franchise gave it the privilege of collecting toll from all vessels passing through. The tolls were first

collected upon the ship's national tonnage as shown by its papers. In 1872 the English gross tonnage was substituted as a basis for tolls, which led to international disputes and the creation of an International Tonnage Commission in 1873. In 1874 the company was compelled by military force to adopt the Commission's rules, and in 1876 they were accepted. In 1878 the British government obtained the practical exemption of certain deck spaces, and in 1899 it was agreed that deck spaces excluded by British rules would be so treated at Suez, but would be taxed when found carrying merchandise and thereafter. This arrangement was easily evaded by shipowners, and in 1902 the company agreed to exempt those portions of shelter-deck spaces which were entitled to it because of their openings and to treat isolated deck spaces by the rules of 1897. But any space once found in use was thereafter to be measured. In 1904 it was agreed that the judgment of the Suez surveyors should determine whether spaces were open or closed, and at the present time deck spaces are divided into three classes and treated as described later in this chapter.

Certificates of tonnage issued by the regularly appointed officials of the various countries are accepted at the Suez Canal, subject to the inspection and interpretation of the Canal authorities.

5. **Panama Canal Rules.**— An act of Congress in 1912 gave the President of the United States power to prescribe the tolls to be charged vessels using the Panama Canal, and a schedule was issued the same year. The Secretary of War was authorized to make the necessary rules, and these were prepared by Emory R. Johnson, Special Commissioner on Panama Canal Traffic and Tolls, in 1913. They are most nearly similar to the Suez Canal rules and provide for the measurement of net tonnage. The gross tonnage includes all available carrying capacity as far as possible and propelling-power deductions are made by the Danube rule. Only one difficulty has arisen in the administration of these rules. The law required that the tolls should be not more than $1.25 per net registered ton. When this law was passed the Panama Canal rules were not in existence and the question has been raised as to what was meant by net registered tonnage when the act was passed. Not the net registered tonnage by Panama Canal rules, it is argued, for these were not in existence. Accordingly, it is the practice to levy tolls on Panama Canal rules at $1.00 per ton, provided the tolls collected do not exceed $1.25

per net ton under American rules. Two sets of rules are therefore in actual operation, the shipowner receiving the benefit of the more liberal treatment. Otherwise these rules have been in use for seven years without appreciable difficulty or change.

The authorized national officials may issue Panama tonnage certificates, subject to correction by the officials authorized by the President to administer these rules.

Summary of Measurement

- I. Methods of measurement
  - Tonnage deck
  - Length
  - Depth
  - Breadth
- II. Spaces exempt from measurement
  - Below tonnage deck
  - Above tonnage deck
    - Because not closed in
      - Hatches
      - Openings in sides
      - Openings in partitions
    - Because of purpose
      - Water ballast
      - Machinery — auxiliary boiler ventilating engine room
      - Navigating
      - Shelter for passengers
      - Toilets
      - Kitchens
      - Bakery
      - Companionways
      - Skylights, domes
      - Hatches
- III. Deductions
  - General
    - Crew Space
      - Crew Toilets
      - Passageways
      - Crews galley
      - Captain's quarters
    - Navigating spaces
      - Steering
      - Capstan and hoisting
      - Chart room
      - Boatswains storeroom
      - Auxiliary boiler
      - Sail room
  - For propelling machinery
    - Principal volume
    - Ventilating spaces
    - Shaft tunnel

Using the United States rules described in previous chapters as a basis, it will be instructive to compare the application of these five rules to the measurement of vessels, indicating the most important respects in which they differ, the reasons for certain provisions, and their deficiencies in some respects. Preliminary thereto it may not be out of place to present for review the outline of the important items in tonnage mearusement shown on the preceding page.

Application of Rules

Tonnage Deck.— The national and canal rules all agree as to what shall be considered the tonnage deck. The lower deck is often replaced by beams and in the case of web-framed vessels is entirely missing, so that the first actual deck from the bottom is considered the tonnage deck. Under the Panama Canal rules a trunk deck or turret deck is considered the upper deck and since the vessel has but two decks becomes the tonnage deck. The space within the turret or trunk is measured as are other 'tween-deck spaces. In the case of English and German rules the width of the turret where it meets the sides is taken as the tonnage deck. The Suez rules calculate separately the space below the tonnage deck and the turret space, in a fashion similar to the British rules. For trunk-decked vessels the width at the top of the sides below the trunk is taken as the location of the tonnage deck (see page 84). Under the British rules the upper deck of the self-trimming vessel is used as the tonnage deck.

Length.— The length is measured in the same manner by all five systems.

Tonnage-Length Divisions.— The British, German, Suez, and Panama rules classify vessels into five groups according to length, dividing the tonnage lengths of these groups into 4, 6, 8, 10, and 12 parts respectively. The length groups have similar boundaries under all these rules. The American rules differ in that, as seen in a preceding chapter, they classify vessels according to length into six groups, and divide the tonnage length of these groups into 6, 8, 10, 12, 14, and 16 parts respectively. The United States requirement tends toward greater accuracy of measure-

ment, but the results have been considered hardly commensurate with the trouble and time involved. The difference caused by measuring 20 sections instead of 12 would not often amount to 1 per cent of the gross tonnage. The Panama Canal measurement rules of 1913 consequently required only 12 divisions for the largest vessel.

Measurement of Depths.— The Moorsom system is followed universally, and consequently the same depth measurements are required by all rules. When a ship has an irregular bottom line, the ship is divided into longitudinal sections at the points where there are abrupt changes in the bottom line. In the Suez rules, however, there appears to be nothing to cover this.

Tonnage under the Tonnage Deck.—As far as the tonnage under the tonnage deck is concerned, it is apparent that all of the rules are in substantial accord and this tonnage for a given vessel is therefore always approximately the same.

Between-Deck Tonnage.— The method of measurement is identical under all the rules, but there is no agreement as to what shall be measured and what exempted. The discrepancy arises from the different interpretation placed upon the expression "permanently closed-in" and similar phrases, interpretations undeniably colored in some instances by the desire of nations to obtain preferential treatment through the understatement of gross tonnage and consequently net. After the British Act of 1854 permanent closed-in spaces were measured until 1875. By 1860, however, vessel-owners demanded some allowance for superstructures and what is now known as a shelter deck. This was originally little more than a substantial awning built above the upper deck, and as such the space below was exempt from measurement, but the natural tendency was gradually to enclose this space as far as possible and still retain the exemption from measurement. In 1864 the United States Measurement Act was adopted and naturally followed the Moorsom Act and the then practice of the British Board of Trade of measuring all spaces sufficiently closed in to be actually available for cargo or passenger carriage. In 1866, due to disputes with shipowners, the British Board of Trade proposed that spaces under the shelter deck should not be measured and were not to be used for freight or for the accommodation of crew or passengers, a proposal which was not accepted; whereupon the Board of Trade proceeded to

measure all such spaces. The shipowners tested the legality of such measurement in the courts. Meanwhile Germany passed a measurement law, in 1872, which embodied the same provisions in respect to shelter-deck spaces as the English law and enforced the same strict interpretation. A year later an International Commission framed the rules for the Suez Canal. These followed the English rules with respect to shelter-deck spaces, but, in view of the controversy then running in England, closed-in spaces were accurately defined and it was provided that shelter-deck space should be measured by providing that "openings will not prevent measurement if the openings can be easily closed in after measurement." The feelings of tonnage experts can be imagined when, after having made such progress, the English House of Lords decided in 1875 that it was illegal to measure the space under the shelter deck of the steamer *Bear*. The reasoning was that the cargo between this covering and the main deck was not cargo stowed and sealed up in a hold but was deck cargo protected against the weather, and that consequently the *Bear* had not a third deck. In 1876, however, to prevent the anomaly of a vessel's actually entering port with a cargo in the space exempted from measurement, an act was passed providing that if cargo was carried in any unmeasured space the space actually occupied by cargo should be measured for the calculation of tonnage dues. This space unoccupied, however, was free. The Royal Commission of 1881 recommended the measurement of shelter-deck space, but without result. The present British instructions advise surveyors to "have regard to the character and structural conditions of such deck erections," not to measure them when they have "one or more openings in the sides or ends not fitted with floors or other permanently attached means of closing them," but if otherwise "so closed in as to be not only available but also actually fitted and used for the berthing or accommodation of passengers," to measure them. The openings in the shelter deck must be of prescribed size.

The present German laws were adopted in 1895 and modified subsequently several times, but the object has constantly been to make the tonnage results coincide with those attained under British treatment, so that while the German law is not identically worded the results have become in practice identical. There is, however, no deck cargo provision in Germany.

The Suez rules remained as strict in respect to shelter-deck space as they were originally until 1899, when an agreement was unofficially made that spaces declared open under British measurement would not be measured unless actually used to stow freight. Evasion by shipowners brought about the abandonment of this agreement in 1902 and the Suez regulations of 1904 provided for the measurement of all shelter-deck space except that in the way of opposite openings in the side plating of the ship.

The Panama rules of 1913 follow the Suez rules as modified in 1904 in the treatment of shelter-deck space.

The following illustration shows the results attained through the diversity of shelter-deck treatment:

THE BRITISH STEAMSHIP *Stephen*

Built of steel, 1910; a freight steamer with accommodations for some passengers, of a type used in the trade between New York and the Amazon; two decks and a shelter deck; coal capacity 1100 tons; average speed around 11 knots; registered length, 376.4 feet; registered breadth, 50.3 feet; registered depth, 23.6 feet.

	United States Rules	British Rules	Suez Rules
Under tonnage deck	3707.36	3607.36	3607.36
Between decks, etc.	1862.96	827.48	1870.34
Gross tonnage	5470.32	4434.84	5477.70

It is apparent that the American treatment has been stricter than the British or German but does not equal the Panama or Suez interpretations.

The only logical method of handling this subject is strictly to measure all space actually closed in, whether theoretically so closed or not. Even though only temporary means of closing are provided, it is evident that these spaces are intended to be used for cargo when cargo is available. If measured, they would probably be provided with permanent means of closing, and it is difficult to see why even the space opposite side openings should be exempt.

Method of Measuring Between-Deck Spaces.— All the countries employ the Moorsom system, the length being divided in accordance with the division of the tonnage length in the various countries and the widths being taken in the same fashion as the widths used in measuring the principal volume.

Superstructures.— The differences in methods of measuring these spaces are hardly worth noting. The Panama rules follow the same system as the American rules. As to the spaces to be measured and those which are exempt, however, the rules differ greatly, but this is best disposed of by considering *seriatim* the various exempted spaces.

Spaces Exempt below the Tonnage Deck.— There are no such spaces of any consequence exempt under any of the rules, with the exception of hatchways and passageways (which are best considered later), and double bottoms. The latter are exempt under all the rules when used exclusively for water ballast and under the Suez rules are always exempt. The national and Panama rules are superior to the Suez rules in this respect, the latter obviously giving considerable advantage to oil-burning vessels carrying fuel oil in double bottoms.

Water-ballast tanks other than in double bottoms are measured by all the rules.

Spaces Exempt above the Tonnage Deck because Unenclosed.— Hatchways are exempt under all the rules up to ½ of 1 per cent of the gross tonnage; the excess above this is measured. These were originally insignificant and were ignored in British measurement but later they increased in size and if over a foot in height were measured, but not otherwise. After 1876 all hatchways were measured and the excess referred to above included in the gross tonnage. Permanent erections made unavailable for cargo or passengers by reason of openings are exempt under all the rules. It is unnecessary to repeat the discussion of the interpretation of "closed" spaces but the method of treating spaces above decks under the present Suez rules is interesting. By the memorandum of 1904 these spaces are divided into three groups:

1. Spaces considered as "closed" under the national rules. These are naturally measured.

2. Spaces considered as "open" under both national and Suez rules, which are, of course, exempt.

3. Spaces considered "open" under national rules and "closed" under Suez rules. The 1897 instructions as to whether a space was open or closed were suppressed and it was left to the judgment of the surveyors to determine from experience and good sense whether or not a deck space could be used for transport-

ing merchandise other than deck loads. This end was reached, however, by the concession that certain forecastle, bridge and poop space was not to be measured, principally that portion of these structures which was least usable.

Spaces above Tonnage Deck Exempt because of Purpose.— These include spaces unavailable for cargo or passengers and mere conveniences for the latter.

1. *Water-Ballast Space.*— This is uncommon above the tonnage deck and is measured by all rules, though usually deducted in ascertaining net tonnage if unavailable for the carriage of cargo or fuel. Under the British rules the water-ballast space at the sides of a self-trimming vessel is exempt, however.

2. *Machinery Spaces.*— Under the Suez rules this space is always measured and deducted later, if not used to hoist cargo. If the donkey engine and boiler are below decks the space occupied is measured by all the rules. If connected with the engine room it is later deducted under all the rules except the Suez rules. The latter treatment is difficult to explain. If these appliances are above decks and not connected with the engine room they are exempt under the American, British, and German rules, for reasons hard to see. They are partly used for navigating purposes and partly for cargo. If connected with the engine room they are measured and later deducted under the British, German, and American rules. Under the Suez and Panama rules the space above decks is always measured, and if exclusively used for navigation and not for hoisting cargo is deducted, which is very logical.

From the accompanying diagram it may be seen that a closed-in space is frequently provided above the crown or top of the engine-room space for light and ventilation, referred to hereafter as light and air space. Under the American rules this space is not added to the gross tonnage unless requested by the owner for the purpose of adding to his engine-room space and consequently his subsequent engine-room deduction. In Great Britain, prior to 1879, light and air spaces from the crown of the engine room to the upper deck were included in gross tonnage and the space so measured later included in engine-room deductions. The space of similar character above the upper deck was neither included in the gross tonnage nor deducted later. A court decision in the *Isabella* case in 1879 compelled the anomalous deduction of such

space above the upper deck even though it had never been measured. This was not corrected until 1889, when it was provided that no space should be deducted unless previously measured and included in gross tonnage. It was also provided that light and air spaces above the upper deck should not be measured except at the request of the owner. The owner may, however, have measured such portion of such space as may be desirable in order to have his engine-room deduction brought to the desired figure. Under the American rules such space is treated as an entirety and either measured or not as the owner elects. The German rules are similar to the British. Under the Suez rules the light and air space is measured if the German rule for engine-room deductions is followed, and if the Danube rule is used the owner is given an option. If such spaces are measured and consequently included as engine-room he forfeits certain exemptions to which he is otherwise entitled, namely, the exemption of open spaces which may exist at the extremities of this space, and all tiers of superstructures below the tier under consideration are measured the same as between-decks.

Under the Panama rules the spaces that are framed in around the funnels and the spaces for light and air are included in the engine room to the extent that such spaces are below the covering of the first tier of side-to-side erections, if any, upon the uppermost full-length deck, whether that deck is or is not fitted with a "tonnage opening." The spaces above the deck or covering of the first tier of side-to-side erections upon the uppermost full-length deck are exempted from measurement.

The treatment under the Panama rules is much superior. Under the other rules similar space on similar vessels will be sometimes included in gross tonnage and sometimes exempt, depending on the ratio of engine space to gross tonnage and the desire of the owner. Under the British rules the owner may still further "jockey" with this space, treating a portion of it in one fashion and a portion in another. In full-cargo vessels this space is likely to be measured, and in high-powered passenger vessels exempted.

3. *Navigating Spaces.*—The spaces for the anchor gear, steering gear, and capstan under American, British and German rules are included in the gross tonnage when situated below the upper deck, and exempted when above said deck. In the former case,

however, they are subsequently deducted, giving the same *net* result as if they had never been measured; but this method of treatment makes gross tonnage incapable of exact definition. The Panama rules measure and deduct such spaces no matter where located, a sound and consistent policy which gives a gross tonnage more nearly approximating the actual closed-in space. The Suez rules are hybrid in this respect, measuring all these spaces but deducting only those located above decks.

The chart, lookout, and signal houses are measured under all the rules and later deducted. The wheelhouse is measured under the Suez and Panama rules and also deducted. Under the United States, British, and German rules the wheelhouse is exempt, which understates the gross tonnage by that amount.

4. *Passenger and Crew Accommodations.*— Cabins and staterooms located on the upper deck to the hull and above are included in the gross tonnage under all rules, with one exception, but temporary arrangements to shelter passengers on short voyages are exempted with the consent of tonnage officials. To be exempt under the Panama rules such shelters must have no connection with the body of the ship other than the props necessary for their support. Under the Suez rules the test is simply whether "open" or "closed-in." The exception referred to is that described in Chapter X — the United States exemption of passenger space above the first deck which is not a deck to the hull — an indefensible and probably accidental provision.

Space for the storage of sails is measured under all rules and, except under the Suez rules, a certain maximum portion may be deducted for sailing vessels.

Skylights and domes are exempt under all rules.

Galleys, cookhouses, condenser, and bakery spaces are all measured under the Suez and Panama rules, wherever situated, and such as are exclusively for the officers and crew may be deducted, wherever situated. Under the national rules they are exempt if situated above decks and measured if below decks, but in the latter case subject to deduction.

Companion houses are exempt under all rules, except when used for smoking rooms or other special purposes.

Passageways are measured when serving measured spaces under all the rules and exempt when serving exempted spaces. Under the American and British rules they may be deducted when serving

deducted spaces, under the German and Panama rules they may be deducted when serving the quarters of officers and crew exclusively, and under the Suez rules they may be deducted only when fitted with lockers, hammocks, etc., for the use of crew and officers and serving crew and officers' quarters.

Toilet facilities for the officers and crew, under American, British, and German rules are exempted if above decks, and measured and deducted if below decks. Under the Suez and Panama rules all such spaces are measured and deducted if used exclusively for officers and crew. Under the Suez and Panama rules passenger toilets are all measured and not deducted. Under the other rules they are measured when below decks, without privilege of deduction, and above decks 1 toilet per 50 passengers, not exceeding a total of 12, is exempt.

While some are technically measurable because serving passengers, it is questionable whether in the interest of public health all these spaces should not be exempt from measurement or at least deducted. They contribute little or nothing extra toward earning capacity, and, on the other hand, contribute greatly to health, comfort, and safety of passengers, officers, and crew.

Measurement of Propeller-Power Space.— The tonnage of the engine room is considered to include the following:

1. Space below the crown of the engine room.
2. Space between the crown and the upper deck framed in for the machinery or for the admission of light and air.
3. Space similarly framed in above the upper deck.[1]
4. The contents of the shaft-trunk or trunks in screw vessels.

The spaces above referred to are measured in similar fashion by all the rules; the product of the mean length, breadth, and depth divided by 100 being considered the cubic capacity. Other spaces jutting into these volumes and not strictly a part thereof are deducted.

Necessity for an Arbitrary Rule.— It has been previously shown that while the space occupied by fuel is very considerable it is indeterminate and changing, varying with the stage of the voyage, length of voyage, possibility of recoaling, efficiency of the machinery, quality of fuel, quantity of cargo, character of the trade, and other factors. The space occupied by fuel cannot

[1] Reference to the Panama rules in this respect is made later.

be accurately measured, therefore it must be assumed that it varies with some other characteristic or characteristics of the vessel, such as the engine-room space.

Three Propelling-Power Rules

1. **The Percentage Method.**— This rule originated in Great Britain. The British Act of 1819 allowed for engine-room space by deducting the length of the engine room from the length of keel to determine the tonnage length. The Act of 1836 provided that the actual space occupied by the engine room should be deducted from the gross tonnage. The 1819 rule was probably not far from correct for vessels of only two or three decks, but the 1836 rule was taken undue advantage of by the construction of vessels with engine and boiler room separated. The space between was not used for machinery or fuel but was included in the engine-room deduction because the space between the forward and after bulkheads bounding the engine and boiler rooms was taken for this purpose. Moorsom was in favor of continuing this system on a practicable basis in the Act of 1854, but, instead, the so-called percentage rule was inserted. Confining attention to the screw-propelled vessels the rule is: When the boiler and machinery space is above 13 and under 20 per cent of the gross tonnage of the ship, the deduction for the same shall be 32 per cent of the gross tonnage. As regards all other ships, the deduction, if the Board of Trade and the owner agree, shall be estimated in the same manner, but either they or he, in their or his discretion, may require the engine-room space to be measured and a deduction to be made of 1¾ times the tonnage of such space. In 1860 the Board of Trade, acting upon the authority of a law which gave it power to make modifications of the tonnage rules for the "more accurate and uniform application thereof and the effectual carrying out of the principle of admeasurement therein adopted," substituted for the percentage rule the rule of 1836. In 1866 the courts, upon application by a vessel owner, held that the Board of Trade had exceeded its authority and the percentage rule regained the place it has since held. As to vessels with engine-room space aggregating 13 per cent or less of the gross tonnage and those with similar space totaling 20 per cent or over, the Danube rule is applied in the former case by the Board of Trade's option and

in the latter because, being more favorable, it is assumed to be the owner's desire. An act of 1907 restricted the total deduction for propelling power in any case to 55 per cent of the vessel's tonnage remaining after other deductions than those for propelling power have been made. Such is the present rule in Great Britain. We will defer the discussion of the percentage rule and examine the Danube rule, which forms part of the British and American systems.

2. The Danube Rule.— This rule had also a British origin. It was part of the law of 1854, as described above, is part of the law to-day, and efforts have been made there to make it the sole rule for propelling-power deductions. But the great majority of British vessels come within the percentage-rule portion of the law. This part of the British system was rejected by the European Commission of the Danube, an international commission established by the Treaty of Paris in 1856, to control the Danube River. The Commission established as its exclusive rule for propelling-power deductions the following: The deduction for propelling power shall be 1¾ times the actual volume of the engine room (150 per cent for paddle-wheel steamers). The rule was consequently known as the Danube rule.

RATIO OF ENGINE-ROOM SPACE TO GROSS TONNAGE

	13 per cent or under	14 per cent to 19 per cent	20 per cent or over	Maximum
United States	Danube	percentage	Danube or percentage	none
Great Britain	Danube or percentage	percentage	Danube or percentage	55 per cent of gross tonnage after other deductions
Germany	Danube *	percentage	Danube or percentage †	none
Suez	For vessels without fixed bunkers, the Danube rule; for all others the German or Danube †			50 per cent of gross tonnage
Panama	Danube for vessel without fixed bunkers and for all others the German †			50 per cent of gross tonnage

* Unless the bureau of registry requires the percentage rule.
† Choice of the owner.

3. The German Rule.— Like the two preceding rules this rule had a British origin, being the rule contained in the Act of 1836 and recommended by the Board of Trade in 1867. It was adopted by Germany in 1873, whence the name. This rule provides for the deduction of the space actually occupied by the engine room and fixed bunkers or oil compartments.

The preceding table summarizes the treatment of propelling-power deductions under the five laws.

Discussion of Deductions for Propelling Power, Crew Space, and Navigating Space

Propelling Power.— The German rule may be quickly disposed of because, since it measures the actual capacity of the engine and fuel spaces, it is obviously equitable if applied alone. Its principal function in existing laws, indeed, is to provide the vessel owner with a recourse in case other provisions appear burdensome. It is, however, applicable only to vessels with fixed bunkers, and for reasons previously explained these are necessarily rare, so that its application is greatly restricted. The history of the percentage rule in Great Britain has been given previously. This rule was introduced into the law of 1854 under protest of Moorsom, and since he had a wholly scientific interest in the subject of measurement, this gave a prevision of its probable workings. The rule was unsatisfactory to the Board of Trade, and after appeal to Parliament the Board of Trade took upon itself the responsibility of substituting another system, with the unfortunate result previously described. The Danube Commission rejected the percentage rule with the full approval of the British representatives. Efforts to repeal it were made in 1871, 1872, 1874 and 1881. It was condemned by the English Tonnage Commission of 1881. By the law of 1907 the amount of the propelling-power deduction was limited to a maximum of 55 per cent of the tonnage remaining after the other deductions had been made. This served to prevent a vessel having a negative net tonnage, a result possible previously. A select committee appointed by the Board of Trade in 1906 considered that sufficiently strong reasons for a change did not exist at that time, but the expert members of the committee dissented from this view. A Parliamentary committee was appointed in 1907 and recommended the law above referred to, limiting the

total possible deduction for engine-room space. Everything was done except to apply the remedy — the repeal of the law. The objections to the percentage system may be listed as follows:

1. It assumes a relationship between the space occupied by engine, boiler and fuel, and the gross tonnage of the vessel, which is fallacious. Even though such a relation did normally exist, the law provides an incentive for the vessel-owner arbitrarily to nullify such relationship by unnecessarily increasing the engine-room space, as shown later. Thus the assumed relationship is vitiated by both economic and legal reasons.

2. The deduction allowed always exceeds the actual space occupied and so violates the principle that the net tonnage should represent the earning capacity. The Danube rule admittedly makes a liberal allowance for this purpose. In an 8000-ton vessel with engine-room tonnage of 1120, the allowance under the Danube rule would be 1960 tons, and under the percentage rule 2560 tons. In ocean-going steamers the actual stowage space available exceeds the net tonnage by from 10 to 12 per cent. In fact, the percentage rule was merely an attempt to favor British tonnage, which in self-defense has been copied by other nations.

3. The percentage rule causes space on the vessel to be wasted merely for the purpose of enlarging the engine-room sufficiently to qualify for the 32 per cent deduction. In a 10,000-ton vessel, for example, if the engine-room and shaft space total 1200 tons the owner is allowed a deduction of 2100 tons. By increasing the propelling-power space to 1400 tons, however, the deduction is increased to 3200 tons, or, in other words, an increase of 16⅔ per cent in propelling-power space carries with it an increase in deduction of over 50 per cent. The object of the shipowner naturally is to have his engine-room space always exceed 13 per cent but by as small a margin as possible. It was testified that in one instance it was necessary to break down the engineer's storeroom and put a partial bulkhead and grating in front of it, so as to allow just a little more space in the engine room to qualify for the 32 per cent deduction.

4. It has already been shown that the option allowed for light and air space permits the owner to use this space as exempted space or as engine-room space. Under the British rules he can even use a portion of the space as he desires. This further complicates the situation by introducing another variable factor into

the propelling-space deduction. The volume of light and air space may be arbitrarily increased in order to obtain the benefit of the percentage rule. The amount of all propelling space, including light and air space, therefore is related not solely to the room occupied by machinery but to the gross tonnage of the vessel as well.

5. The percentage rule discriminates between vessels. Thus, in three 8000-ton vessels, the first with engine-room space of 1020 tons would be entitled to a deduction of 1785 tons, the second with engine-room space of 1060 tons would be entitled to a deduction of 2560 tons, and the third with engine-room space of 1580 tons would be entitled to a deduction of 2560 tons. One or more of these vessels are comparatively unjustly treated. Secondly, the rule makes no distinction as regards length of voyage, although a vessel making short runs is using much less space for fuel and has available much more for cargo than a vessel making long ocean voyages. Thirdly, the rule discriminates between high- and low-speed vessels and consequently between freight and passenger ships. A 12,000-ton passenger vessel with 2280 tons of propelling-power space would receive 3840 tons deduction, while a 12,000-ton freight steamer with 1680 tons of propelling-power space would receive the same allowance of 3840 tons, in spite of the fact that the former high-speed vessel naturally requires more machinery space and more fuel than the latter, which can steam at the most economical speed. It is true that the great bulk of vessels have from 13.1 to 19.9 per cent of their gross tonnage devoted to space of this character, but even within this group there are discriminations, and a rule which is favorable to the majority is still not equal to one which is equitable to all. Though this is now a comparatively unimportant matter, it might be pointed out that the rule, being unduly favorable to certain types of steamships, discriminates against the sailing vessel.

6. The effects of the rule, instead of being minimized by the passage of time, have been aggravated. With the increase in the number of decks the gross tonnage has increased in comparison with the engine-room space, so that the allowance has tended to exceed the latter by an ever-increasing margin. The increasing efficiency of the marine engine, giving greater power per unit of size has further tended to increase the ratio of gross tonnage to engine-room space. Internal-combustion engines will further ac-

centuate this tendency. More efficient propelling machinery requires less fuel per unit of work done, and the already too liberal allowance for fuel space becomes still more excessive. Increased coaling facilities decrease the average supply on hand and free additional space for carrying cargo which has been deducted for propelling purposes.

The Danube rule is apparently more scientific and equitable, and, in the absence of accurate measurement of fuel space, must be accepted as the best. It is open to four objections:

1. It assumes a relationship between machinery space and fuel space. While in general this is probably true, there are many exceptions, the fuel space depending upon the length of voyage and distance between coaling stations also.

2. While superior to the percentage rule, the Danube rule also violates the principle of making the net tonnage represent earning capacity. For many vessels engaged in coasting and short sea voyages the fuel space required falls considerably below 75 per cent of the machinery space. Even as regards ocean steamers, if this proportion was accurate in 1854 it cannot be at the present time, in view of the improvements which have taken place.

3. Like the percentage rule, this rule does not improve with time. Many of the important changes in marine propulsion are designed to reduce the fuel consumption, and the fuel space has been reduced much faster than the machinery space. Take for example an oil-burning steamer. The space required for the machinery is but little less than for a coal-burning engine but the oil fuel requires only 60 per cent of the space required for coal.

4. Without attempting to reach a decision or propose a remedy, it is pertinent to inquire whether the enforcement of the Danube rule with the same percentages as used for coal-burning steamers will not create an unfortunate precedent which will be as hard to eliminate in the future as the percentage rule has been in the past. Knowing that the fuel required for oil-burning and internal-combustion engines occupies much less than 75 per cent of the machinery space, why accustom the owners of these types of vessels to a too liberal allowance which they will demand for a long time to come? Furthermore, the Danube rule applied indiscriminately to coal and oil-burning vessels will discriminate against the former to a considerable degree, thus adding to the oil-burner's possible economic advantage an artificial legal subsidy.

In framing the Panama Canal rules in 1913 the question of adapting the propelling-power deduction rule to newer methods of propulsion was considered, or rather the question of choosing between existing rules in the light of such newer methods. In the oil-burning vessel the machinery space is approximately the same

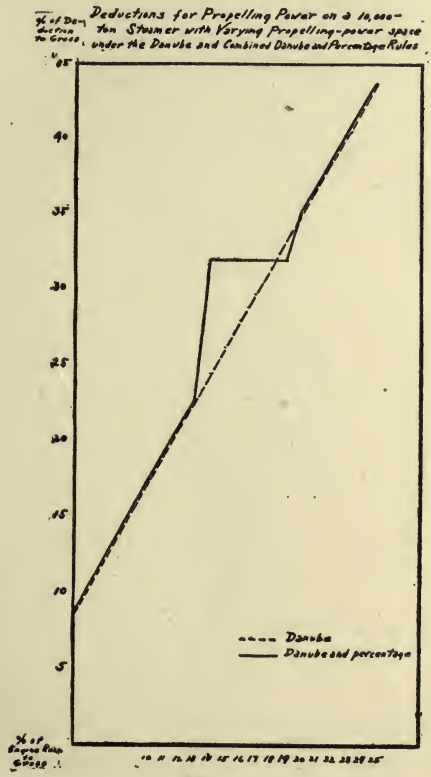

FIG. 67

as for a coal-burner, while the fuel space required is considerably less. But the fuel space saved is not entirely available for cargo, inasmuch as the space which would have been occupied by coal bunkers is not always usable for cargo. In a specially constructed vessel, however, a considerable portion of this space would be converted into usable space. Furthermore, if the fuel oil is carried in double bottoms the net tonnage is increased by the amount of space so used, under the Panama rules. In view of these facts the Danube rule was felt to be satisfactory, an opinion in which

the writer cannot fully concur. In the internal-combustion oil engine type of carrier there is a very considerable reduction in machinery space and a still greater reduction in fuel space. Under the existing national rules the saving in machinery space would not always be taken advantage of, because of the necessity of bringing the engine-room space up to at least over 13 per cent of the gross tonnage. The reduction in fuel space leads to a great increase in dead-weight capacity. In the internal-combustion gas engine there is very little saving, if any, in machinery space, and the saving in fuel space is not equal to the internal-combustion oil engine. The conclusions reached in the preparation of the Panama rules were:

1. The use of fuel oil increases the gross and net tonnage of the vessel under the Panama rules, which partially offsets the saving in fuel space.

2. The difference in fuel space between the oil-burning and coal-burning steamer is not deemed great enough to necessitate the immediate adoption of a special rule applying only to the comparatively small number of vessels now (1913) equipped with oil-burning steam engines.

3. The number of large merchant vessels equipped with internal oil-combustion engines is still comparatively small (1913), the engine is still in the process of development, and it is not yet certain whether the vaporized, oil-gas, producer-gas, four-cycle Diesel, two-cycle single-acting Diesel, or two-cycle double-acting Diesel will prove superior.

4. It would be difficult, at the present time (1913), to arrive at a general average ratio of fuel space to machinery space for internal-combustion engines of different types.

5. Liberal propelling-power deductions will be of assistance in bringing more promptly into service marine engines of the greatest efficiency and economy.

Crew Space.— Under the American rules the sleeping, dining, and toilet space for the crew was deducted from the gross tonnage, except when used by or for passengers. A minimum space of from 72 to 100 cubic feet and from 12 to 16 superficial feet per seaman is required by law. Under the British rules a minimum of 120 cubic feet and 15 superficial feet is required, under the German rule a minimum of 3.5 cubic meters and 1.5 superficial meters. Under the Panama rules each of the above spaces

is subject to the minimum and marking requirements of the navigation laws of the several countries. These spaces are deducted under all the rules with the following exceptions. Under the British, American and German rules galleys, condenser space, cook houses, and bakeries are deducted if below decks but not if above decks, because the latter were exempt from measurement and not included in the gross tonnage. Under the Panama rules all crew space, wherever situated, is measured and consequently deducted. Under the Suez rules all such space is measured and deducted if used exclusively for officers and crews. Toilets for the crew are exempt if above decks and consequently are not deducted, while those below decks are deducted if exclusively so used, under British, American, and German rules. Under the Suez and Panama rules all such space is measured and deducted if used exclusively for officers and crew. Passageways are deducted when serving other deducted spaces exclusively under all the rules except the Suez, where they are not deducted unless fitted with lockers, hammocks, etc., for use of crew or officers and serving crew and officers' quarters. The master's cabin is deducted under all the rules except the Suez. This is true also of the doctor's cabin, which under the Suez rules must be actually occupied by the doctor.

Navigating Spaces.— These consist of allowances for the anchor, steering gear, capstan, wheelhouse, chart house, lookout house, signal house, sail room, boatswains' stores, and donkey engine and boiler. Under British, German, and American rules the anchor, steering gear, capstan, and wheel house space are deducted if below decks and not deducted if above decks because exempted. Under the Suez rules such spaces are deducted if above decks and not deducted if below decks. Under the Panama rules all such spaces are deducted. Chart, lookout, and signal spaces are deducted under all rules. Space for the storage of sails in sailing vessels is deducted under all rules except Suez, up to 2½ per cent of the gross tonnage. Under the Suez rules no deduction is provided for. Boatswains' stores are deducted under all rules except the Suez, but under the Panama rules this deduction is limited to 1 per cent of the gross tonnage for vessels of 1000 tons or over and to 75 tons for any vessel. Space taken by donkey engine and boiler is measured under all the rules if below decks, and if connected with the engine room it is deducted under

all the rules except the Suez. If above decks this space is measured and deducted by the German, British, and American rules if connected with the engine room. If not so connected it is exempted. Under the Suez and Panama rules such space is always measured and if the engine is used for handling cargo is not deducted; otherwise deducted.

Under the German and Suez rules the allowances for deductions other than for propelling-power space are limited to 5 per cent of the gross tonnage; under the other rules they must merely be reasonable in extent.

With respect to crew and navigation spaces the Panama rules are superior to the other rules because, as has been probably noticed, they consistently include such spaces in the gross tonnage and deduct them in order to arrive at the net tonnage. Under the other rules these spaces are treated with lamentable confusion, though the net differences in tonnage as a result are negligible.

International Tonnage

The first instance of anything approaching international uniformity in tonnage was in 1860, when the Danube Commission adopted the English tonnage of 1854 as a basis for tolls. Factors were used to convert tonnage reached by other national rules into its English equivalent. The British law of 1862 provided that when any foreign nation adopted the British system of measurement the tonnage of vessels as stated in its official papers would be accepted at British ports without remeasurement. The British government accordingly urged other nations to adopt the British system in furtherance of uniformity and a commission was appointed in France, of which the results were nil. As a consequence of the British law, however, the Moorsom system and the Moorsom ton were adopted by the United States in 1865 and by Denmark in 1867. From this time on it became the practice to enter into reciprocal tonnage agreements by which the measurements of foreign countries were recognized by the home nation. While other nations were attempting to adapt their measurements to the existing British system, however, the British courts handed down the decision previously described, whereby the action of the Board of Trade in 1860 respecting engine-room deductions was held to be illegal, and other nations began to modify their rules

in self-protection. In 1871 the Danube Commission gave up the English rules and adopted its own rules for engine-space deductions and in 1876 adopted the Suez rules. In 1873 the International Tonage Commission met at Constantinople and formulated the rules subsequently known as the Suez rules, which were primarily designed as a basis for international agreement. England again disappointed the hopes of international uniformity, however, by failing to adopt these rules in 1874. Because of the dominant position of Great Britain other nations felt obliged to adopt those rules to which she insisted upon adhering. Italy adopted the percentage rule for propelling-power deductions in 1882; Japan, in 1884; Norway, in 1893; Denmark, Germany, and the United States, in 1895; Holland, in 1899; Russia, in 1900; Spain, in 1902; France, in 1904. Meanwhile the Moorsom system and the Moorsom ton had been adopted by the following countries:

United States	1865	Netherlands	1876
Denmark	1867	Norway	1876
Austria-Hungary	1871	Argentina	1877
Germany	1873	Finland	1877
France	1873	Greece	1878
Italy	1873	Russia	1879
Chile	1875	Haiti	1882
Sweden	1875	Belgium	1884
Turkey	1875	Japan	1885
Spain	1874		

At the Pan-American Conference, which met in Washington in 1890, the unnecessary number and variety of tonnage taxes and dues were recognized and the discriminations which resulted, but the recommendations of the Conference were based upon an insufficient knowledge of the difficulties involved in the tonnage question and were inadequate and impracticable. At a meeting of the International Institute of Statistics in Paris, 1889, the diversity in the unit of measuring vessels, shipbuilding, and commerce was fully described, and resolutions urging an international tonnage were adopted, but without result.

Up to the present time, therefore, two steps have been taken toward international uniformity, (1) the adoption of the Moorsom ton and Moorsom system of measurement, and (2) the international recognition of tonnage certificates. Regardless of the system of measurement adopted, however, no uniformity will

exist until the method of treatment of the various spaces is identical, and, although the importance of the subject has increased with the growing international navigation and commerce, diversity still prevails. The formulation of the Panama Canal rules in 1913 offered another opportunity to adopt a common system which was not taken advantage of.

The benefits of an international system, which have probably been already indirectly indicated, may be summarized as follows:

1. Statistics of navigation and commerce would be simpler, more intelligible and more accurate.

2. A shipowner or operator would understand the size of the vessels he employed or purchased.

3. The annoyance and expense of remeasurement would be eliminated.

4. Taxation would be less involved and more equitable.

REFERENCES

1. JOHNSON, E. R.: "Report to Secretary of War on Panama Canal Traffic and Tolls." Washington, 1913. Chaps. IV, V, VIII, IX, XII and XIII and Appendices VIII, IX and XI. (Comparison of English, German, United States, Suez, and Panama rules.)
2. HERNER, HEINRICH: *"Hafenabgaben und Schiffvermessung."* G. Fisher, Jena, 1912. Part II. (Comparison of German and Suez rules.)
3. WHITE, W. H.: *Manual of Naval Architecture.* Murray, London, 1894. Chap. II. (Comparison of English and Suez rules.)
4. BERET, V.: *"Etude sur le Jaugeage."* Société anonyme de publications périodiques, Paris, 1905. (Comparison of English, French, German, and Suez rules.)
5. WALTON, THOMAS: *Know Your Own Ship.* Griffin & Co., London, 1917. Chap. VIII. (Comparison of British, Suez, and Panama rules.)
6. JOHNSON, E. R.: "Report to Secretary of War on Panama Canal Traffic and Tolls." Washington, 1913. Chap. XII. (On international uniformity in tonnage.)
7. BERET, V.: *"Etude sur le Jaugeage."* Paris, 1905. Pp. 21–30. (On international tonnage.)

See also references at close of Chapter XI.

CHAPTER XIII

THE MEASUREMENT OF SAFETY

The three elements of safety in ocean transportation are efficient seamanship, proper loading, and adequate construction. The first is not pertinent to this volume; the second was considered in the section dealing with freeboard; leaving the third for discussion here. Methods of gauging the safety of vessels from a consideration of their structure have existed since the inception of ocean transportation, the ancient lender on bottomry having exercised his judgment on this problem, but at the present time organized classification societies are principally relied upon for this service, the results of their efforts being evidenced by the publication of a register. This records particulars of the vessel and, by assignment of a symbol, "registers" the society's opinion of it. We will first examine the purposes served by the inspection and classification system of such associations.

Purposes of Classification

In general, the inspection of a vessel to determine its seaworthy qualities is of interest to all persons connected with ocean transportation. Insurance companies and underwriters have been, for many years, accustomed to depend upon the information furnished to guide them in accepting risks and fixing rates. Since they have not the opportunity of personally inspecting every risk which is offered, they must in many cases rely largely upon the particulars of the vessels made available by the "register." As one underwriter expressed it in his testimony before a Congressional investigating committee, "the average underwriter bases his rates primarily on his experience with an ownership, a trade, or a route, but for individual vessels he must know the physical character of the vessel," and often he is asked to write insurance upon a vessel which is in a far-off port, thus forcing him to resort to such printed information as may be available.

The second group of interested persons consists of passengers, shippers, and consignees whose persons and goods are for the time being entrusted to the vessel. In the complexity of present economic life the inspection and classification of vessels aids them in an indirect way, for a shipper or consignee, instead of keeping a close watch upon the condition of a vessel through the published results of the classification societies, is much more likely to have his attention directed to any unsatisfactory condition by an increase in the rates charged to insure the cargo. The passenger receives these benefits in an even more indirect manner since the defects of the vessel increase the insurance premium on the hull and this places the operator of the vessel at a competitive disadvantage. However devious the course pursued, it cannot be denied that these benefits ultimately accrue to persons in this category.

More direct are the benefits received by those who hire vessels. The register furnishes an approximate guide in the selection of a vessel which is suited to their needs, and protects them against contracting for the charter of a vessel notoriously unsafe, for which they might find it difficult to secure a crew or insurance, and to which they would be reluctant to entrust their goods.

The public authorities are also in a position to receive the benefits of these services, although this has not been fully taken advantage of in the United States. In England the organization and machinery of the classification society has been utilized to make inspections required by law, so that, as described in a previous chapter, an official load line may be fixed by recognized societies. The work of such societies is also accepted in many cases where some standard is necessary for legislative purposes.

It is weighty evidence of the value of this work that vessel owners in practice are forced to avail themselves of the facilities afforded by these societies. It is not compulsory for a vessel owner to have his vessel "classed" by a society, but the lack of classification makes it difficult to charter or insure it. A vessel built without the supervision of the societies' inspectors may subsequently receive a class upon request, but the time of building furnishes a favorable opportunity to have a survey made without loss of time. As expressed in the report of the Commissioner of Corporations on Water Transportation, "the opinion expressed by a body of experts possessing the amplest means of ascertaining the condition of a ship and enjoying in the highest degree the con-

fidence of all persons engaged in shipping is therefore regarded as the best and most desirable evidence of the true state of the vessel, so that shipowners, generally speaking, submit to the conditions imposed by the committees of classification or organizations corresponding thereto in order to obtain their testimonials." So that at the present time no large vessel sails without a classification certificate.

From the objective standpoint the work of the classification societies may be summarized as:

1. The inspection and classification of vessels and the publication of the results in a form facilitating reference.

2. The accumulation of a code of rules as a guide in vessel-construction, designed to make a vessel approximately fit for the trade intended.

In satisfactorily ascertaining the safety of a vessel three divisions appear. In the first place, the fitness of the vessel for its purpose may be approximately gauged by mathematical principles similar to those employed in estimating the necessary strength for other structures. The vessel is tested like a girder, a bridge, or a foundation. These mathematical calculations must secondly be supplemented by a considerable amount of experience, inasmuch as the actual stresses and strains encountered by vessels under many varying conditions do not exactly correspond to those ascertained by calculation. This experience in its highest state of completeness and uniformity can be supplied only by somebody who is constantly and continuously interested in the subject. Thirdly, some public or semipublic institution is a prerequisite for the inspiration of confidence and insurance of uniformity; very little confidence would be engendered by the certificate of an unknown surveyor, no progress would be made if a multitude of different rules on different bases were simultaneously in use. For these reasons classification societies have come to occupy an important place in the shipping world, and we may briefly examine their development in England.

Development of Classification Societies

Although in early days it might be possible to inspect a vessel every time it was offered for insurance or for hire, the repetition

of inspections became exceedingly burdensome when tonnage increased. The early underwriters accordingly kept lists of ships for their own guidance in insuring, and it was only natural that such private papers should in course of time pass from hand to hand. They were probably first put into print in England about 1726, but no copies of these early lists now exist. The oldest copy of a Register of Shipping now extant bears the date 1764–1766. It shows the former and present names of the vessel, the owner and master, its customary trade, tonnage, number of guns carried, the port and year of construction, and the classification given it. The letters *A, E, I, O,* and *U,* indicated the classification of the vessel, and the letters *G, M,* and *B* the character of the equipment. A register of 1768–1769 was improved by references to the vessel's rig and information regarding repairs. The letters *a, b, c* now designated the vessel classification and the numerals 1, 2, 3, the condition of the equipment, a combination of these being the origin of the familiar expression of praise "A 1."

The registry of shipping up to this point was probably controlled and operated solely for the benefit of the insurance fraternity. In 1797 a new system of classification was introduced which based the rating entirely upon the place of build and the age of the vessel, and thus London-built vessels received a great advantage. Accordingly, in 1799 dissatisfied shipowners started the New Registry of Shipping. The Underwriters' Register (or Lloyd's Register as it was called after 1829) was known as the *Green Book* and the shipowners' register as the *Red Book.* These vessel registers were competitors for 38 years, but in 1837 were amalgamated and the Society of Lloyd's Register assumed practically the form it has to-day. This is a voluntary association of those interested in shipping, who support the activities of inspection and classification by subscription to the product. Up to 1837 it was a body closely allied with, and probably controlled by, the Lloyd's underwriters. After 1837 it acquired a fair representation of shipowners. From the time of the amalgamation the second function we have mentioned, that of prescribing rules for construction, began to be exercised. It would serve no purpose here to trace the fight of representatives of the outports for greater recognition, the gradually increasing minuteness in the rules for construction, the promulgation of rules for iron ships in 1855,

the institution of periodical surveys of vessels, the adoption of the principle in 1870 that the dimensions of the vessels and not their tonnage should govern the size of scantlings, the provisions made for the survey of ships abroad, and the introduction of machinery surveys. As a result of the efficiency of its work and the large number of vessels of Great Britain on the seas, Lloyd's Register came to occupy the highest position in the shipping world as an authority upon vessels.

Process of Registration

The registration procedure is practically identical in all societies. When the plans for the construction of a vessel are drawn, they are submitted to the headquarters of the registration society. The primary cause of the establishment of the American Bureau of Shipping was the refusal of Lloyd's to allow plans to be passed upon in the United States, although the opinion was expressed that plans were finding their way to London which American interests would prefer to keep at home. If the submitted plans are approved the work of construction commences, but additional explanation may be requested or modifications suggested, and this usually results in some negotiations before approval. The material put into the vessel is manufactured under survey and subjected to the tests required by the rules, and the various fittings must also receive the approval of the surveyors. The case of the *Quistconck,* built at Hog Island, the equipment of which failed to receive a Lloyd's rating because of a defective anchor chain, may be recollected. The vessel might be said to be built under the eye and control of the surveyors. Upon completion, a classification is assigned. A vessel may be offered after completion for examination and registration, but this process is not very satisfactory. This oversight is maintained for twelve years after launching, a periodical survey being conducted every four years. In case of an accident necessitating repairs between these periods, the repairs are similarly supervised. The boilers are subject to inspection at least once a year, after six years. In order to maintain her class, the vessel must pass these surveys, but naturally some vessels drop from the very highest to a lower class during the period by reason of deterioration.

Description of Lloyd's Register

On the following page a reproduction is given of a page from a recent Lloyd's Register. We might take the steamer *Glengyle* for purposes of explanation. In the first column appear the number of the vessel in the register, her official number, and the code letters assigned for identification purposes. In the second column appear the name of the vessel and its former name if a change has occured. Thus the steamer *Glenford,* on the same page, was formerly the *Christina.* Tables elsewhere facilitate the tracing of vessels through changes in name. In bold type the *Glengyle* is described as a steel twin-screw steamer. The master from 1884 to 1914 was R. Webster, and the vessel is fitted with three steel decks, electric light, refrigerating machinery, and wireless. In column 4 are shown the gross tonnage, underdeck tonnage, and net tonnage. Columns 5, 6, and 7 give the particulars of classification. This vessel is marked ✠100A1. The black cross signifies that the vessel was constructed under special survey. The designation 100A means that an iron or steel vessel was built according to the rules in force since 1869, of the highest quality. As the vessel becomes poorer, its rating is changed to 95A, 90A, 85A, 80A, and 75A. Vessels marked simply A1 are of iron or steel but constructed for a special purpose. Iron vessels built according to the rules in force between 1864 and 1871 are classed as ⩓, ⩔, or ⩒, and wooden or composite vessels are marked A in red or A in black, or Æ. The mark * indicates iron vessels built with thicker plating than required for ⩓. The figure 1 following 100A indicates that the vessel's equipment has been sanctioned; the mark –, that the equipment is deficient compared with the rules. The date shows that the last survey was made in October, 1914, and the port of survey is given as Newcastle. The machinery is marked with letters to indicate its classification. the significance of letters being found by reference to tables in the rules. In red letters it is indicated that the machinery and boilers and refrigerating machinery received a Lloyd's certificate by special survey while building, in October, 1914. Column 7 shows the date when the tail shaft was last seen, in this case while building. From columns 8 and 9 we find that this vessel was constructed in 1914, by Hawthorne, Leslie & Company, at Newcastle, and that its anchors and chains

1 No. in Book. / Official No. / Code Letters.	2 Steamer's Name. Material, Rig, &c. *Master.* *Late Name if any.* Special Surveys. No. of Decks, &c.	4 Regist'd Tonnage Gross. / Under deck. / Net	5 Particulars of Classification. Character. — ✠ for Special Survey. Date of last Survey.	6 Port of Survey.	7 Where Classed. Equipment Letter	* Date when tail shaft last sent.	8 Built. When. — Ship. — Engines	9 By Whom. — Where.	10 Owners.	11 Regist'd Dimensions. Deck Erections, &c. Length.	Breadth.	Depth.	12 Port of Registry. Flag.	13 Engines. No. & Dia. of Cylinders.—Stroke Boiler Pressure. NHP=Horse power by Society's formulæ; RHP=power by Ship's Register Particulars of Boilers & Furnaces Engine Maker's Name.	14 Moulded depth. Freeboard amidships / Corresponding draught. ft. in.	15 Registers in which classed, if not in L.R. Distinct Port of Trade Port
496 86010 WFHR	**Glenford** Steel Sc 3 Mst Sr *J.McNicol* 05–10 *ss* Liv. No. 3–9,06 (*ex* Christina) *ss* Ard. No. 2–14 *Well deck Mchy. Aft* 1 *Dk*(*Stl*)	494 346 192	✠ 100 A 1 3,14 BS 2,15 ✠ LMC 3, 14	Ard	*h*	5,13	1893 7mo	S. Mc Knight & Co. Ayr A&CP	Ford Shppg Co. Ltd. (Mann, Macneal & Co. *Mgrs.*) *B* = *DB*/91'120*t FT*	165·0 | 26·1 | 10·8 279'B14'F26' BK 7' *T* 87*t APT* 8,	Glasgow British	C. 2Cy. 20″ & 40″–33″ (*s*) 120 lb 90 RH 3 *BHCem* Muir & Houston, Glasgow	13 ″ 4 ″ ″ 9 13 ″ 4	
497 135841 JCVQ	**Glenfoyle** Steel Sc *Elec. light Mchy. Aft* 1 *Dk*	1680 1519 1051					1913	N. of Irelnd S.B.Co. Ltd. Londonderry	J. Playfair	250·0 | 42·5 | 17·4 F39'	Lndnderry British	*WB*	T. 3 Cy. 16″, 27″ & 44″–30″ 97 RHP MacColl & Pollock, Ld. Sld		CL
498 119134 VRLN	**Glenfruin** Steel Sc Sr *E.B. Mockness* –15 *ss* Cff. No. 2–13 1 *Dk*(*Stl*) & *deep framing*	3097 2965 2020	✠ 100 A 1 1,15 BS 4,14 ✠ LMC 1, 15	Cff	*v*	1,15	1904 5mo	A. Rodger & Co. Pt. Glasgow *Lloyd's* '14 *CP*	S.S. Glenfruin Co. Ld. (Easton, Greig & Co.) *WB* = *Cell D Ba*; *fu* £124' *f* 138' 75 1*t*	320·1 | 47·5 | 23·0 P25'B11'8'F30' FK *T* 95*t*	Glasgow British	T. 3 Cy. 24″, 40″ & 65″–42″ (*s*) 160 lb *80 lb* NDB 03 419 NHP 6 *BHCem* *APT* 95*t*	25 ″ 7 3 4 ″ 0½ 21 ″ 11	
499 101837 NDPM	**Glengariff** Steel Sc Sr *H. Blanchard* –15 *ss* Qns. No. 3–5,04 *Ref. Mchy.* *ss* Qns. No. 2–12 *Elec. light* 2 *Dks*(*US tl*–ws)	1286 983 548	✠ 100 A 1 1,15 ✠ NB 6,08 ✠ LMC 2, BS 1,15	Qns	*p*	1,15	1893 8mo	Wigham Richrdsn & Co Newcastle A&CP	City of Cork Steam Packet Co. Ltd.	264·2 | 35·2 | 17·1 P36'B146'F40' BK 9″ *WB* = *Cell D B* 155'	Cork British	T. 3 Cy. 28″, 44″ & 72″–48″ (*r*) 160 lb *80 lb* NDB 03 419 NHP 2 DB, 12*cf*, *gs* 252, *hs* 7175 W ghm Richrdson & Co. Nwc.	18 ″ 1 1 2 2½ 17 ″ 2	BT till 1,16
500 3160	**Glengarry** Iron Pad Sk *J. Carmichael* –14 (*ex* Edinburgh Castle)	124 117 62					1844	Smith & Rodger Glasgow	David MacBrayne, Ld.	148·5 | 16·3 | 7·2 Q8*t* len 75	Glasgow British	1 Cy. 36″–42″ NB 63 45 RHP Smith & Rodger, Glasgow		BT till 5,15
501 87241 HDJN	**Glengoil** Iron Sc Sr *ss* Sld. 2nd No. 3–7,10 1 *Dk*(*Irn*) & *Spar dk*(*Irn*–ws) 3 *tr B*	2963 2917 1915	✠ 100 A 1 *Spar dk* 10,13 ✠ LMC 7, 10 ✠ NB 4,06 BS 10,13	Npt	*u*	N 10,13	1882 11mo	J. L. Thompson & Sons. Sunderland A&CP	The Admiralty *R* – *Cell D Ba* 92′ *u*	320·0 | 40·0 | 20·2 pt ND 93 27·5 ND 801 BK 10′ *E* 16′ *f* 136′ 466 *t APT* 38*t* *Tpd*. 96	Newcastle British	T. 3 Cy. 21″, 35″ & 56″–48″ (*s*) 160 lb NDB 96 226 NHP 2 SB, 6*cf*, *gs* 102, *hs* 3480 N.E. Marine E. Co. Ld., Nwc.	30 ″ 4 3 7 ″ 2 24 ″ 6	
502 109290 QJRW	**Glengorm Castle** Steel Twin Sc Sr *D. H. Hoskins* –11 (*ex* German) *Ref. Mchy.* Sub. Sig. Wireless 3 *Dks*	6769 4036 4299					1898	Harland & Wolff, Ld. Belfast	The Union-Castle Mail S.S. Co. Ltd.	440·3 | 53·2 | 21·6 P231′*t* W297′*t* 29·6 F113′*t*	S'thamptn British	T. 6 Cy. 19″, 31″ & 52″–48″ 375 NHP Harland & Wolff, Ld. Bel.		BT till 6,15
503 136711 JGVS	**Glengyle** Steel Twin Sc Sr *R. Webster* 64–14 *Elec. light* 2 *Dks*(*Stl*) 3 *rd dk*(*Stl*) *Ref. Mchy.* Wireless in No. 6 hold	9395 8705 5996	✠ 100 A 1 10,14 ✠ LMC 10, 14 ✠ Lloyd's R MC 10, 14	Nwc	*ft*		1914 10mo	Hawthorn, Leslie & Co. Ld Newcastle *Lloyd's* '14 *CP* 132	Glen Line (McGregor, Gow & Co.) Ld. *WB* = *Cell D Ba* FK & BK 2½′ *u* £45′ *f* 195′ 151 6*t*	500·2 | 62·3 | 34·7 P60′B132 F88′ *DT a* 33′ 1170*t FPT*	London British	T. 6 Cy. 24″, 40½″ & 68″–48″ (*s*) 200 lb 988 NHP 8 *BHCem* 5 SB, 20*cf*, *gs* 380, *hs* 14775 FD 174 *tAPT* 49*t*	37 ″ 6 3 8 ″ 5 29 ″ 7	BT till 10,15
504 —	**Gleniffer** Steel Twin Sc Sr *Elec. light* *Ref. Mchy.* Wireless	9000	100 A 1 (*Class Contem plated*)				1915	Hawthorn, Leslie & Co. Ld Newcastle	McGregor, Gow & Co.	500·0 | 62·3 | 34·6 P61′B192′F87′	Glasgow British	T. 6 Cy. 42″, 40½″ & 68″–48″ Wilsnd Slpwy. Co. Ld. Nwc.		
505 78677 RHCT	**Glenisla** Iron Sc Sr *J. Mitchell* –13 6th Survey, Bly. 9,08 1st Survey, Nwc. 5,13 2 *Dks*(1 *Irn*)	1263 1169 796	✠ A 1 * 1 4,13	Shl	Lv		1878 1mo	W. B. Thompson Dundee	J. Mitchell & Sons	250·1 | 32·7 | 20·3 P33′B61′F34′ pt ND 90,03 BK 8′ &c. *WB* = *Dba*	Dundee British	C. 2 Cy. 32″ & 54″–38″ NB 13 150 NHP 3 *BH* ✠ RBH. 60′ *f* 42′ 81*t*	21 ″ 4 3 3 ″ 3 2 SB, 4*pf*, *gs* 70, *hs* 2650 19 ″ 2 W. B. Thompson, Dundee	

FIG. 68

were proved at a machine under the superintendence of Lloyd's Register (Lloyd's A & CP). The letters A & CP would have indicated merely a machine recognized by Lloyd's Register. Column 10 gives the owner's name — the Glen Line, McGregor, Gow & Company, Ltd. Column 11 shows the length as 500.2 feet, the breadth 62.3 feet, and the depth 34.7 feet, the deck erections consisting of a poop 60 feet long, a bridge of 192 feet, and a forecastle of 88 feet. We find also from column 11 that this vessel has water-ballast arrangements (WB), a cellular double bottom (Cell DB), a flat keel and bar keel 2½ inches in depth (FK & BK), 8 cemented bulkheads (8 B H Cem), a deep tank 33 feet long with 1170 tons capacity (DTa 33 feet 1170t), a fore peak tank of 174 tons (FPT 174t), and an after peak tank of 49 tons (APT 49t). Column 12 shows that the vessel is British and is registered at London. Column 13 gives the particulars regarding the engine, this vessel having triple-expansion engines with 6 cylinders, their dimensions and stroke being given, a boiler pressure of 200 pounds to the square inch, a nominal horse power of 998, 5 single-ended boilers, 20 corrugated furnaces, 380 square feet of grate surface, 14,775 square feet of heating surface, using forced draft. The engine maker's name is also given. Column 14 shows the molded depth 37 feet, 6 inches; the freeboard amidships 8 feet, 5 inches; and the corresponding draft, 29 feet, 7 inches. The last column shows the registers in which the vessel is classed if other than Lloyd's and the date of the vessel's Board of Trade certificate. This gives an idea of the information conveyed by the Register about a vessel, surely a very considerable amount to be included in a space of less than 4½ square inches, as in this case. There remains to be explained only the basis for that very important feature in the digest, the classification or rating, in this case 100A1. The classification rules which form this basis are considered in subsequent sections.

Other Important Registers

Classification societies similar to Lloyd's have been established in all the important maritime countries, but with the exception of France have never attained similar importance, for reasons previously mentioned. There are the British Corporation in Great Britain, the Bureau Veritas of France, the Germanischer

Lloyd of Germany, the Veritas Austro-Ungarico of Austria, the Nederlandische Wereinigung of Holland, the Norske Veritas in Norway, the Registro Nazionale Italiano in Italy, and the Veritas Hellene in Greece. Of these the American Bureau of Shipping is the most important.

American Bureau of Shipping.— This was incorporated in New York in 1862 as the American Shipmasters' Association, and its name was changed to the present title in 1898. It was organized to collect and disseminate shipping information, ascertain and certify the qualifications of masters and promote safety at sea. In 1867 there was established the Record of American and Foreign Shipping, a shipping register, and in 1882 the American Lloyd's Register was purchased and combined with this Bureau, giving the right to use the name American Lloyd's. In 1908 it absorbed the United States Shipowners', Shipbuilders', and Underwriters' Association. It has eight officers, a board of managers composed of the insurance, ship building, ship-operating, repairing, and scientific representatives, an executive committee, finance and audit committee, and a classification committee composed of four shipbuilders, four vessel-owners and operators and one insurance man. There is a membership limited to 100 and composed of persons interested in shipping, who pay no fees, the income for the support of the organization being derived from the fees charged for making surveys. There is also necessary a corps of surveyors in the United States and abroad, some doing work exclusively for the American Bureau and others being nonexclusive surveyors. The corporation issues no stock and pays no dividends, being a purely mutual coöperative organization for rendering a necessary service in shipping and insurance circles. This organization maintained a more or less precarious existence for a number of years being, as one of its officers expressed it, "the child of one insurance company — the Atlantic Mutual." During this period (1916) it absorbed the Great Lakes Register, a society for classing vessels on the Great Lakes. Three attempts were made in 1913 and 1915 by the American Bureau to amalgamate with British Lloyd's, but without success. The latter attempt furnished the opportunity for starting a strong American Register. It was thought that it would be possible to have vessel plans passed upon by the American committee without reference to London, and the question was put to Lloyd's Register in this

form: Suppose an American naval architect designs a new ship and your American committee, formed under this coalition, passed the plans for that ship, will Lloyd's, in London, accept the decision of the American committee or will the plans have to go to London? The secretary of Lloyd's responded that the plans would have to go to London, all the plans would have to go to London. Whereupon the reorganization committee decided to reorganize its own classification society. This society received the hearty support of the United States Board during the World War. The number of exclusive surveyors greatly increased, and while in 1916 it was classing 8 per cent of American vessels, in 1919, due largely to the business distributed to it by the Shipping Board, it was classing 68 per cent of American vessels.[1] Its importance to an American merchant marine can hardly be overestimated.

Description of the American Register.— Below is given a sample page of the Record of American and Foreign Shipping, the most prominent American register. For purposes of explanation we will use the steamer *Lake Ledan*. The first column shows the register number, official number, and signal letters of the vessel, being followed by the name of the vessel, prefixed by a Maltese cross, indicating that the vessel was built or repaired under inspection. If the name of the vessel has been changed the former name is also given, as in the case of the *Lake Linden*, formerly the *War Cloud*. In the second column the vessel is described as a one-deck (1D) bulk carrier, built of steel with 4 water-tight bulkheads (4 BH), with submarine signals and water-ballast tank (W. Bal.). Column 3 indicates that it is a screw steamer, and its nationality is given as American in column 4. Column 5 shows its hailing port as Superior, Wisconsin. In columns 4 and 5 combined its length is given as 251 feet, its breadth as 43.7, its depth as 22.2 feet, and its molded depth as 24 feet 2½ inches. It has a poop extending for 25 feet, a bridge 64 feet long, and a forecastle 23 feet in length. Column 6 furnishes the net tonnage (1432), the gross tonnage (2369), and the dead-weight tonnage (3525). In column 7 it is stated that the freeboard allowance is 3 feet 4 inches at a draft of 21 feet. Columns 8 and 9 show that it was built in June, 1918, by the Superior Shipbuilding Company

[1] Testimony of S. Taylor before Subcommittee on the Merchant Marine and Fisheries, July 16, 1919. "Hearings on Marine Insurance."

No. Off. No. Signal Letters.	Name of Vessel and Master. Material, Detail of Decks, etc.	Rig.	Nation.	Hailing Port. Reg. Dimensions. Lth. | Bth. | Dth. Deck Erections Mid.	Tons Net Gross D.W.	Freeboard. Corresponding Draft.	Built. When	Where. Builder.	Owners.	Remarks. Engines, Boilers.	Ship—Class—Date of Last Survey. No., Date, and Port of Last Periodical Survey. Engines & Boilers—Class—Dates. Tail Shaft Drawn—Date.	Other Classification.
340.. ✠ 216,390 LKTC	**Lake Lasang** Steel 1D;Bulk carrier;W. Bal 4BH	Scw	Am 251 P25'	Wyand'te 43.8 | 24.2 B64' F23'	1447 2371 3525		1918 6	Wyandotte, (Detroit [Mich S. B. Co.)	U. S. Shipping Board	3Cyl TE20,33,54x40; 2SB14'6"D11'L;114GS; 5466HS;WP180lbs;1250IHP; EAC;Dkd,s rps8,19	✠A1Ⓔ ✠AMS	
341.. ✠ 216,522 LMBQ	**Lake Ledan** Steel 1D;Bulk carrier;SUB.SIG;W.Bal 4BH	Scw	Am 251 P25'	Superior 43.7 | 22.2 | 24' 2½" B64' F23'	1432 2369 3525	3' 4" 21'	1918 6	Superior, (Superior [Wis. S. B. Co.)	U. S. Shipping Board	3Cyl TE20,33,54x40; 2SB14'6"D11'L;114GS; 5466HS;WP180lbs;1250IHP; EAC;Dkd,s rps1,19	✠A1Ⓔ ✠AMS	
342.. ✠ 216,156 LKMJ	**Lake Lemando** Steel 1D;Bulk carrier;W. Bal 4BH	Scw	Am 251 P27'	Cleveland 43.7 | 22.2 B64' F26'	1451 2370 3525		1918 5	Cleveland, (American [Ohio S. B. Co.)	U. S. Shipping Board	3Cyl TE20,33,54x40; 2SB14'6"D11'L;114GS; 5466HS;WP180lbs;1250IHP;EAC	✠A1Ⓔ ✠AMS	
343.. ✠ 216,678 LMHK	**Lake Lesa** Steel 1D;Bulk carrier;W. Bal 4BH	Scw	Am 251 P25'	Superior 43.7 | 22.2 B64' F23'	1428 2352 3525		1918 7	Superior, (Superior [Wis. S. B. Co.)	U. S. Shipping Board	3Cyl TE20,33,54x40; 2SB14'6"D11'L;114GS; 5466HS;WP180lbs;1250IHP;EAC	✠A1Ⓔ ✠AMS	
344.. ✠ 216,844 LMSC	**Lake Licking** Steel 1D,Bulk carrier;SUB.SIG;W. Bal 4BH	Scw	Am 250.5	Wyand'te 43.8 | 22.2	1445 2368 3525		1918 9	Wyandotte, (Detroit [Mich. S. B. Co.)	U. S. Shipping Board	3Cyl TE20,33,54x40; 2SB14'6"D11'L;114GS; 5466HS;WP180lbs;1250IHP;EAC	✠A1Ⓔ ✠AMS	
345.. ✠ 217,474 LPNK	**Lake Licoco** Steel 1D;Bulk carrier;W.Bal 4BH	Scw	Am 251	Saginaw 43.5 | 22 | 24'5"	1418 2350 3545	3' 2½" 21' 4½"	1919 3	Saginaw, (Saginaw [Mich. S. B. Co.)	U. S. Shipping Board	3Cyl TE22,37½,60x42; 2WTB3'6"D12'10"L;138GS; 5184HS;WP200lbs;1600IHP EAC;Dkd,s rps9,19	✠A1Ⓔ ✠AMS	
346.. 216,277 LKGT	**Lake Lida** Steel 1D;Wireless;W.Bal 6BH	Scw	Am 250.5 P27'	Manitow'c 43.7 | 20.4 B64' F26'	1287 2177 W. Bal		1918 5	Manitowoc, (Manitowoc [Wis. S. B. Co.)	U. S. Shipping Board	3Cyl TE20,33,54x40; 2SB;WP180lbs;272NHP.		BL

FIG. 69

at Superior, Wisconsin. It is owned by the United States Shipping Board (Col. 10). Column 11 gives the details of the engines and boilers and indications of special features. This vessel has engines of 3 cylinders (3 Cyl) of the triple-expansion type (TE), the dimensions of the cylinders being given, 2 single-ended Scotch boilers (2 SB), the dimensions of which are also given, a grate surface of 114 square feet (114 GS), a heating surface of 5466 square feet (5466 HS), a working pressure of 180 pounds to the square inch (WP 180 lbs.) The engines have an indicated horse power of 1250 (1250 IHP), and a certificate has been granted for the electrical apparatus. The vessel was docked for small repairs in January, 1919. Column 12 shows that this vessel received the highest classification, ✠A 1 Ⓔ, as is true of all other vessels on this page, except those for which no mark appears in this column, which are not classified by the American Register. If of construction less adequate for its purposes this vessel would have been marked A 1½ or A 2. Some vessels are indicated as being classed only for particular trades. The Ⓔ applies to the equipment. The mark ✠A.M.S. signifies the highest classification of the American Bureau of Shipping and special survey during construction for machinery and boilers. Where the equipment is not in compliance with the requirements of the rules a dash is substituted for the mark Ⓔ. In the final column it is seen that this vessel is not classified with other classification societies, but we find other vessels on the same page classed in the British Lloyd's (BL).

Lloyd's Rules and Tables for Classification

The construction of the vessel is largely regulated by the size of the scantlings required. Until 1870 it was the custom to prescribe such size in proportion to the under-deck tonnage but the tonnage of a vessel is rather uncertain until completed and takes no account of dimensions. Consequently, a double system of numerals was adopted, one numeral being assigned to the transverse parts and one to longitudinal parts. This is simply a convenient method of taking into consideration the dimensions of the vessel. The transverse or framing numeral is arrived at by the addition of the vessel's molded depth and breadth. These numerals are tabulated for vessels of increasing size and under

each numeral are given the scantlings and spacings of transversely disposed parts required for a vessel of such dimensions. The longitudinal or plating numeral is the product of the transverse numeral multiplied by the length of the vessel. These numerals are likewise tabulated and under each is given the sizes for longitudinal parts, shell plating, keel, decks, stringers, etc. The following table from Holms gives an idea of the resulting numerals:

Plating number	Framing number	Approximate dimensions		
		L	*B*	*D*
2,500	27.0	95	19.5	7.5
5,000	35.5	140	24	11.5
10,000	48.5	208	31	17.5
15,000	58.0	261	36	22
20,000	66.0	305	40.5	25
25,000	73.0	343	44	29
30,000	79.5	378	48	31
35,000	85.0	412	51	34
40,000	91.0	441	54	37
45,000	96.0	468	57	39
50,000	100.5	496	59.5	41
55,000	105.0	520	62	43
60,000	110.0	545	64.5	45
65,000	113.5	568	66.5	47
70,000	118.0	591	69	49
75,000	122.0	612	71	51

By reference to the approximate numerals, as stated, the necessary requirements for the vessel may be ascertained. By experience these must be modified and adapted for vessels of various design and structure.

It must not be supposed, as is sometimes done, that the thickness of the shell plating or other scantlings is based, in the first instance, on the mere magnitude of the numerals; for instance, the bottom plating of a vessel whose second numeral is 20,000 is not twice as thick as it is in one having a numeral of 10.000. There is no fixed relation; in the former it is .54 inch, in the latter .44 inch. The scantlings appropriate to various sizes and types of vessels were decided in the beginning more or less tentatively or empirically, and, in the course of time, as dictated by experience, they were suitably modified. The numerals may be regarded merely as a means of identification, to indicate, as it were, the general size of the vessel, and what scantlings are in her case appropriate. If all vessels, though varying in size, were of identical proportions and form, it would be

a matter of indifference what the numerals were; a single dimension, the length, breadth, or depth, or the volume, or the tonnage would serve equally well as a means of proclaiming the size and what scantlings would be most appropriate. But vessels vary greatly in form, and it is therefore difficult to devise numerals which, while simple in application, will form in all cases a theoretically correct basis.[2]

In other societies other methods are followed, the British Corporation, for example, setting out the requirements under the length, breadth, depth and combinations thereof.

American Bureau of Shipping Rules for Construction

It is, of course, impossible to show the many different elements which enter into the requirements for vessel-building in order to meet the requirements of classification. All that can be done is to take a few items from the book of rules with the object of showing the value of this system of supervision and the thoroughness with which the survey is attempted.

1. Keels, Stems, and Stern Frames.— The dimensions of these parts are principally governed by the length of the vessel as measured from the stem to the after side of the rudder post along the summer freeboard line. The requirements are tabulated in a form similar to that given below.

L	KEEL PLATE			CENTER GIRDER		
	Thickness			Thickness		
	Breadth	Amidships	Ends	Amidships	Ends	Boiler space
100	39	.40	.32	.28	.24	.36
125	40	.44	.36	.30	.26	.38
150	40	.50	.38	.32	.28	.40

2. Frames. The dimensions and strength of frames is in accordance with two factors, M and K. The factor M is obtained by considering the spacing of the frames, the height amidships, and the distance from the summer load line to one-half the height. The factor K is obtained by considering the spacing of the frames, the distances from the lowest tier of beams to a designated distance above the freeboard deck and a percentage of the breadth

[2] Holms, *Practical Shipbuilding*, Longmans, Green & Co., London, 1916, p. 47.

varying from one-half to one-quarter. A tabulation of the dimensions required then enables one to find the demands for any combination of values for M and K, as is shown by the following sample of a table:

CHANNEL FRAMES

	Values of M		
K	42	46	50
0	9 x 3 x .42 x .44	9 x 3½ x .38 x .50	etc.
2	9 x 3½ x .38 x .50	9 x 3½ x .38 x .50	etc.
4	9 x 3½ x .38 x .50	9 x 3½ x .42 x .50	etc.
6	9 x 3½ x .38 x .50	9 x 3½ x .44 x .55	etc.

3. Beams. The requirements for beams are principally dependent upon the length and the value of a factor N, the latter being derived from the spacing of the beams, the character of the deck and the height of the freeboard and other decks. The following table shows the derivation of the dimensions:

CHANNELS FOR BEAMS, BULKHEAD STIFFENERS, ETC.

	Values of N		
L	10	12	15
15.5	.....	6 x 3 x .42 x .48	etc.
16.25	6 x 3 x .32 x .44	7 x 3 x .38 x .48	etc.
17.	6 x 3 x .42 x .48	7 x 3 x .38 x .48	etc.

4. Shell Plating. This is dependent upon the length and spacing of frames and the freeboard. For example:

	SPACING	THICKNESS				
L		Bottom in single bottom vessels	Sides bottom in double bottom vessels	Ends	Fore-castle	Poop
100	21	.32	.30	.26	.22	.22
105	21	.32	.30	.26	.22	.22
110	21	.32	.32	.26	.24	.24

5. Decks. The requirements for decks are influenced by the length, breadth, and freeboard of the vessel.

STRENGTH DECK AND TOPSIDES — ONE DECK

LENGTH	FREE-BOARD	THICKNESS			AREAS FOR BREADTHS OF				
		Sheer strake	Topside and streamer plate	Deck	12	16	20	24	28
100	6	.30	.30	.18	3	4	6	7	9
	5	.30	.30	.18	3	4	6	8	10
	4	.30	.30	.18	3	5	7	9	10
	3	.30	.30	.18	3	5	7	9	11

6. Equipment. Sails, boats, anchors, chains, hawsers, compasses, windlass, anchor cranes, hawse pipes, steering gears, etc., are all covered by the rules. We might take as an illustration anchors, chains and hawsers, which are governed by the tonnage of the vessel, ascertained by a rough calculation, using the length, breadth, depth and coefficient of fineness.

Many other items, such as rudders, keelsons, double bottoms, stanchions, pillars, girders, bulkheads, ceiling, riveting, cementing, and painting, etc., are considered in the rules but the foregoing is sufficient to give some conception of the method by which the construction of vessels is regulated and the adequacy of the construction, material and equipment tested. This method differs little in fundamental principle from that of Lloyd's; though the arrangement of tables and statement of formulas may vary similar factors are considered in arriving at results.

The Commissioner of Corporations, in a report in 1909, gives the following Comparison of the ratings of the American Bureau, Lloyd's Register and the Bureau Veritas:

American Bureau	Lloyds Register	Bureau Veritas
A 1	A 1	3/3–1.1
A 1½	A 1	5/6–1.1
A 1¾	A 1 red	5/6–2.1
A 2	A 1 red	5/6–2.1
A 2½	AE 1	3/4–2.1
A 3	AE 1	1/2–3.2

REFERENCES

1. Commissioner of Corporations: "Report on Transportation by Water in the United States." Washington, 1909. Pp. 360–365. (Description of American classification societies.)
2. KIRKALDY, A. W.: *British Shipping.* Paul, Trench, Trubner & Co., London, 1914. Book II, Chap. V. (Description of history and operations of Society of Lloyd's Register.)
3. Lloyd's Register: "Annals of Lloyd's Register." London, 1884. (History of Lloyd's Register and system of classification.)
4. HOLMS, C.: *Practical Shipbuilding.* Longmans, Green & Co., London, 1916. Chap V. (Brief history of Lloyd's, explanation of Lloyd's rules and brief discussion of the British Corporation and Germanischer Lloyd's rules.)
5. THEARLE, S. J. P.: "The Classification of Merchant Shipping," paper before Greenock Philosophical Society, January 15, 1914. Lloyd's Register Printing House, London, 1914. (The value of classification and classification societies.)
6. Lloyd's Register: Rules for the Classification of Vessels.
7. American Bureau of Shipping: Rules for Building and Classing Vessels. 1917.
8. Lloyd's Register of Shipping. Annually.
9. The Record of American and Foreign Shipping. Annually. American Bureau of Shipping, New York.

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